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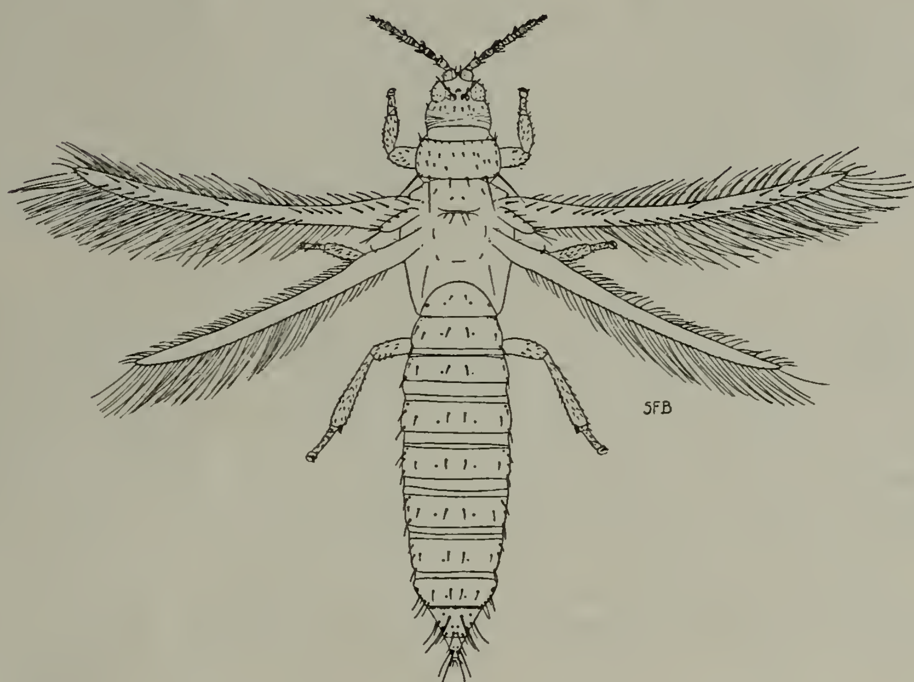
THE PEAR THRIPS IN CALIFORNIA

STANLEY F. BAILEY



Female pear thrips (greatly enlarged)

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CONTENTS

THE PEAR THRIPS IN CALIFORNIA[1]

STANLEY F. BAILEY[2]

SINCE THE PEAR thrips, *Taeniothrips inconsequens* (Uzel), was introduced into California about 1900, several serious outbreaks have occurred in prune- and pear-growing areas. In certain districts this insect has become a major pest, and more effective control has been demanded. The present study was made necessary by the epidemic of 1929 to 1934, when fruit prices were low and the thrips was causing an increased loss despite the control program then being used.

Moulton (1905, 1907*a*, 1907*b*, 1909)[3] and Foster and Jones (1911, 1915) worked out the life history of this pest. Since that time, questions have arisen concerning the causes of the sporadic outbreaks. This eleven-year investigation, therefore, has included not only control methods, but the factors influencing the cyclic tendency of the insect, together with a general method of predicting the increase. The present report on history, distribution, and control has been made as complete as possible, since the older publications on the pest are largely out of print. New data, which may be of value to entomologists and growers, have been included.

HISTORY

The first published record of this insect is its original description from Bohemia in 1895 by Uzel. Williams (1913, 1916) writes as follows:

> The species has without a doubt been in Europe for many years, not usually, however, being injurious. T. Major, in a "Treatise on Insects Most Prevalent on Fruit Trees and Garden Produce" (London, 1829), says on pp. 87–90, on the "thrip" on peach and nectarine, that "as soon as the least verdure appears, both larvae and adults are found, the latter becoming nearly black." They commence feeding on the edges of the young leaves as soon as they put forth in the spring, and also prey on the bloom before it expands.
>
> The above account of the habit and time of appearance leaves very little doubt that this is the same species, so that we have evidence of the species existing in England nearly a hundred years ago.

Collinge (1911) records finding this thrips on plum blossoms in England during 1909 and 1910. In addition Tullgren (1917) brings forward an interesting record from Sweden: specimens in Trybom's collection are dated May 20, 1890. And in 1899 this species was reported from Hungary.

In North America the spread of the pear thrips, because of its economic importance, has been recorded in some detail. Ehrhorn (1905) wrote that thrips "have again appeared in several sections and have done considerable damage to the buds, blossoms, and leaves of deciduous as well as evergreen trees. One species, *Euthrips fuscus,* in particular has been very destructive to the buds and blossoms of prune, apricot, and peach trees in the Santa Clara Valley." In 1904 Miss S. M. Daniel described this pest as a new species,

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[3] See "Literature Cited" for complete data on citations, which are referred to in the text by author and date of publication.

Euthrips pyri, from pear blossoms at San Leandro, California, only a few miles from San Jose. Serious economic damage was first attributed definitely to this insect in 1904. Growers, however, recollected similar bud damage in certain localities in the Santa Clara Valley for several years previous (Moulton, 1905). Apparently, therefore, the pear thrips had been in California since 1900 at the latest, because, as we now know, several years would be necessary for the population to reach epidemic proportions. During 1904, similar injury occurred in the fruit-growing districts in Suisun, Vacaville, and along the Sierra Nevada foothills (Auburn and Newcastle). Moulton (1907*b*) reported the insect from San Benito and Sacramento counties. According to Quaintance (1909), it was generally distributed in the orchard districts in Contra Costa, Solano, Yolo, and Placer counties (Newcastle). Quaintance prophetically declared: "It is also quite probable that the insect will eventually make its appearance in other states on the Pacific coast, and that it may make its way to Eastern orchards." This prediction was quickly fulfilled, for Parrott (1911, 1912) wrote that the thrips had been in the Hudson River Valley about five years before the damage was realized. It was reported from New Jersey in 1911, Pennsylvania in 1912, Maryland in 1913 (Scott, 1914), British Columbia in 1915, Oregon about 1917, Ontario in 1918 (Hewitt, 1915; Treherne, 1919), Washington (Essig, 1926), and Connecticut, 1938.[4]

Returning to its spread in California: the distribution was extended to Napa and Sonoma counties by 1911; San Joaquin County (Sacramento River district), 1912; Marin, Monterey (Essig, 1913), and San Mateo counties, 1920 (Essig, 1931). During the last epidemic the writer collected the thrips from additional areas: Lake, El Dorado, and Mendocino counties, 1934; Santa Cruz and Yuba counties, 1938; Nevada County, 1941. Undoubtedly it had been in the pear-growing districts of these counties for many years without being recognized.

DISTRIBUTION

In the past forty years the pear thrips has undoubtedly reached its maximum distribution in California. Its discovery in one of the oldest deciduous-fruit-growing districts there was perhaps to be expected, since nursery stock was early introduced from Europe to Santa Clara. Authorities unanimously believe that this pest came to North America (and probably also to South America) in soil adhering to the roots of nursery stock from Central Europe.

Its spread was largely northward from Santa Clara Valley, the southmost limits being Hollister in San Benito County, the Santa Cruz district, and Monterey County. It is found in all the Bay counties and northward to Ukiah in Mendocino County, Scott's Valley in Lake County (Bailey, 1935, 1937), and the Sierra Nevada foothill fruit areas of Nevada, Placer, and El Dorado counties. Along the lower Sacramento Delta, the thrips has been irregularly injurious in pear and cherry orchards adjoining the river in Yolo, Sacramento, and San Joaquin counties. The only recorded infestation in the central valleys is in the Dantoni district of Yuba County, along the Yuba River. Specifically, then, besides the places just listed, the pear thrips occurs in San Mateo, Alameda, Contra Costa, Solano, Napa, Marin, and Sonoma counties in practically

[4] This record from Connecticut is based on a letter from the late W. E. Britton, dated February 8, 1938, stating that the pear thrips occurs at Greenwich.

all the fruit-growing districts (fig. 1). The writer has personally collected and identified it from all the above-mentioned counties except Monterey and San Mateo.

As for altitude, the insect has been collected by the writer on pear and prune trees (occasionally, on ceanothus, California laurel, madrone) from sea level

Fig. 1.—Distribution of the pear thrips in California as of 1942, and degree of injury caused.

to about 2,500 feet in the Vaca Mountains, the Santa Cruz Mountains, on Mount Saint Helena and on Mount Howell, and several hundred feet higher in Nevada and El Dorado counties on the western slope of the Sierra Nevada —in other words, chiefly in the Upper Sonoran Life Zone. In no instance during twelve years of collecting thrips has this species been found on native trees and shrubs more than a few hundred yards away from orchards. In California, at least, its distribution is definitely correlated with commercial plantings. In

abandoned orchards the population dwindles rapidly when cultivation and irrigation cease. Small numbers are then scarcely maintained on willows, ceanothus, and California laurel adjacent to orchards only (as determined by emergence traps placed under these hosts).

In North America this insect has been reported on both the Atlantic and Pacific coasts. Since 1918 there has been only a single other published record of its spread—one from the state of Washington (Essig, 1926). On the East Coast the pear thrips has been reported[5] in New York, New Jersey, Pennsylvania, Maryland, and Connecticut. Only in New York, however, does it appear to be really established. One isolated collection was made near Beamsville, Ontario, in 1918 (Ross, 1919). On the West Coast it is well known in British Columbia (Vancouver Island), Oregon, and California, and occasionally found in Washington (Essig, 1926). The writer identified *Taeniothrips inconsequens* in 1935 from specimens submitted by R. Schopp, from Sumner and Puyallup, Washington; and more recently from a collection on cherry made by C. J. Sorenson at Perry, Utah, on April 18, 1942. Idaho has had a quarantine against the pear thrips (State Order No. 25), but repealed it in 1939 as "no longer necessary for the protection of Idaho's pear industry from said pest" (Anon., 1940).

In North America this thrips is found established between about 36° and 49° north latitude.

The recorded world distribution includes France (Vuillet, 1914); Italy, Denmark, Germany, Bohemia, Austria (Priesner, 1920, 1925, 1926; Zacher, 1924); Finland, Norway, Sweden (Ahlberg, 1925); Crimea, Turkestan (Moulton, 1933); England, Scotland (Bagnall, 1911); Central Asia (Moulton, 1933); Cyprus (Priesner, 1939); and Japan (Kurosawa, 1939). Also the pear thrips is known in South America from Argentina and Brazil. Throughout the world, apparently, it is confined within about the same limits as in North America—about 36° latitude (both north and south of the equator), but in Europe northward to about 60° latitude. Seemingly, therefore, this insect, if introduced, could readily survive in southern Australia, New Zealand, possibly Capetown (South Africa), and northern China, and perhaps at higher elevations nearer the equator.

HOSTS

A suitable host for the pear thrips is one which, within the distribution of the insect, blooms during the emergence and egg laying of the adults in the spring. Such a host must furnish succulent tissue for the larvae, shade the ground during hot weather, and maintain itself for several years in moderately moist soil. Irrigated deciduous orchards, although not native hosts, are definitely preferred and are far more favorable to the thrips' increase. Most of its true host plants are deciduous trees and shrubs; but it is also found on evergreens—for example live oak, toyon, and California laurel. Annuals and perennials, in California at least, normally do not act as true host plants on which reproduction takes place.

[5] J. D. Hood of Cornell University states in correspondence that he has definitely determined the pear thrips from New York, Maryland, and Virginia, as well as from Ontario and British Columbia. The records from New Jersey, Pennsylvania, and Connecticut have not been verified. Many of the records of this species in foreign countries are also unconfirmed by experienced thysanopterists.

The fruit trees attacked, in descending order of injury done them, are as follows: pear, prune, plum, cherry, apple, peach (and nectarine), apricot, and almond. Besides these crops, fig, grape, quince, and walnut have yielded incidental collections of the pear thrips.

In this state, reproduction may take place on certain ornamentals near infested orchards—roses, flowering varieties of peach and plum, acacia, Oregon grape, bridal wreath, viburnum, toyon, and wisteria—as well as on maple, box elder, dogwood, poplar, cottonwood, buckeye, bladdernut, California live oak, California laurel, *Ceanothus* spp., madrone, wild cherry, willows, and poison oak.

Many other plants are recorded as hosts (Watson, 1923), though the insect does not necessarily reproduce upon them. Such a list can be expanded almost indefinitely by careful spring collecting in the gardens and fields adjoining orchards. Some of these plants previously listed by others, as well as new ones from the writer's field notes, are as follows: fir, shadberry, currant, lilac, anemone, vetch, mustard, geranium, miner's lettuce, skunk cabbage, elderberry, daisy, dandelion, hawthorn, wild oats, filaree, dock, *Andromeda,* and various grasses.

ECONOMIC IMPORTANCE

To estimate the economic loss of a crop from insect damage is difficult. The factors affecting crop loss or reduction are numerous, variable, and complex. Local conditions, cultural practices, age and vigor of the trees, vary from district to district. The annual loss from pear thrips in California has never been completely surveyed.

In estimating such depredations in monetary terms, one would have to consider, for any one season, the following factors: reduction in crop as compared with normal production, cost of sorting scarred fruit, depression of the price resulting from the sale of off-grade fruit, and cost of insecticides and their application.

Foster and Jones (1915) give the loss to prune growers in the Santa Clara Valley as follows:

Year	Loss, in dollars	Year	Loss, in dollars
1904	30,000	1908	600,000
1905	300,000	1909	900,000
1906	150,000	1910	1,200,000
1907	450,000	1911	600,000

For this eight-year period the average annual loss was $528,750. These figures do not include the cost of spraying. For the same period "the total damage to the fruit industry of the State of California since the first appearance of the insect aggregates, it is believed, at least $6,630,000."

After this early outbreak the pear thrips became much less serious; it occasioned no widespread loss till the recent epidemic of 1929–1937. Between 1912 and 1928, however, it was extending its range, and small local infestations kept attention focused upon it. In the season of 1932, during which the damage was acute, the loss in the Healdsburg district of Sonoma County alone was estimated by the packing-house officials at $200,000. Total crop losses occurred, the same year, on many individual properties in Santa Clara, Contra Costa, Napa, and Solano counties.

In Oregon, Lovett (1921) writes as follows:

Crop yields are materially reduced in quantity and quality unless an organized and intelligent spray program is adopted. . . . It must be conceded that up to date in Oregon there are many other contributing factors which have influenced the indifferent yields and generally devitalized conditions of the orchards. This fact does not materially change the general situation of the presence and destructive possibilities of the thrips in the infested areas.

Injury to prunes is known to be as high as 90 per cent in the Willamette Valley (Wilcox, 1931).

In British Columbia, Cameron and Treherne (1918) conservatively wrote: "It is not possible to give figures with any degree of accuracy illustrating the loss of crop that occurred annually on Vancouver Island. It can be quite confidently stated, however, that in the last seven years the prune and pear crops have been a negligible quantity in certain sections."

No figures are available on the crop loss from this insect in New York.

Over a ten-year period on a given property, the degree of injury may fluctuate from nothing to a total destruction of either pear or prune crops in the county of Sonoma, Napa, Solano, or Santa Clara. One could calculate the average annual loss from pear thrips rather accurately if data were available on production costs (including labor and spray materials) and on the reduction in quantity and quality (as reflected by annual returns to the grower) from thrips damage for 1923–1932 or 1933–1942, which would include both epidemic and nonepidemic seasons. Since such records are not available, we could bring forward only rough estimates or guesses. The damage should not, however, be belittled: in some districts injury occurs every year, necessitating an annual control program. In the counties mentioned above, the thrips is justifiably considered a major pest.

INJURY CAUSED BY PEAR THRIPS

The injury caused by the pear thrips has been thoroughly described and illustrated by previous writers. Those familiar with the pest well know the injury and what it means to the crop.[6] Since, however, the older publications are no longer available and new growers annually enter the business, a brief discussion will be given here.

Primarily, this insect causes two types of injury: loss due to reduction of the crop by the adult or "black thrips," and harm done to the quality of the crop by the larva or "white thrips." Some writers list a third type—namely, the damage caused by the egg laying, which weakens the stems and (during severe infestations) causes shriveling and dropping of the flowers and small fruits. This type of injury is really a part of the adult activity and directly reduces the quantity of the crop.

Immediately upon emerging from the soil the winged adults make their way in under the scales of the opening buds. The rasping and sucking of the mouth parts cause gumming, scarring, or blackening of the calyx and stem, the appearance and relative severity of the injury depending on the type of fruit attacked. Often the bud injury prevents blooming altogether or results in a light crop of distorted, short-stemmed fruit. This feeding injury extends over

[6] The pear thrips has been considered a possible vector of pear blight, but has never been proved a carrier (Bailey, 1935).

several weeks and is particularly severe in a delayed spring, when the buds open slowly. The first individual trees or buds to break dormancy usually evidence the most severe damage. This is sometimes true also of the south side of a tree in contrast to the north or shaded side. Unqualified general statements should not, however, be made. The stage of development of the buds and their rate of growth up to full bloom largely determine the degree of injury. In

Fig. 2.—After the fruit buds have been killed, heavy larval thrips infestations often entirely blacken or "burn" the young leaves of Imperial prune.

addition, the length of time elapsing between the peak of emergence and full bloom has an important bearing on the loss. If, for example, most of the adults have emerged up to the green-bud stage of prunes or the early cluster-bud stage of pears and then an unfavorable spell of weather (or a warm winter) retards the bloom, the bud damage quickly reaches a maximum.

Two extreme conditions constitute exceptions: in a season of very light emergence the injury is negligible and these differences are obscured; on the other hand, in seasons of extremely heavy emergence (800 to 1,000 thrips per square yard of surface), nearly all buds are killed irrespective of the factors mentioned above. In such instances, when no suitable buds are available for egg deposition, the adults migrate to less severely injured trees. The result is a local shifting of the focus of the heaviest emergence the following year.

Scarring and scabbing of the fruit by larvae occurs after petal fall. The tendency of the larvae to cluster and feed in a concentrated area on the surface of the small fruit results not only in blotches, streaks, and pits on the skin but in flat-sided and apple-shaped mature fruit. Only in exceptionally severe cases will the larvae cause fruit drop. Serious leaf injury, though rare, does occur on Imperial prunes (fig. 2) and on cherries (fig. 3) in some districts. As a rule the unfolding leaves are blackened or "burned" at the edges, so

Fig. 3.—Pear-thrips injury to cherries. The curled, ragged leaves and shrivelled fruit are caused chiefly by the larvae. Only two fruits in two clusters have set.

that they become cup-shaped when expanded; or the injured tissue along the midrib and veins later drops out, leaving a ragged or "shot hole" appearance.

Certain special cases and variations in the type of injury had best be discussed under the individual crops.

Injury to Pears.—The most characteristic symptom of thrips injury to pear buds is the bleeding or gumming of the fruit buds shortly after they begin to swell. The feeding punctures of the adults cause the sap to flow readily, especially in the Bartlett variety; and often, if damp weather occurs at this time, a blue mold grows on this exudate. The buds turn black (figs. 4 and 5) and drop before blooming when there are heavy infestations (ten or more thrips to the bud). The fruit that does set is usually twisted and scarred (fig. 6). The leaf

Fig. 4.—Pear buds, enlarged to show injury; such buds develop into misshapen and short-stemmed fruit.

Fig. 5.—Upper row, extreme left, pear fruit buds killed by the adult thrips; extreme right, cluster in which one or two individual fruits have developed normally; center, injured clusters.

Lower row, later stage of development of injured pears, illustrating short stems and curled leaves. By this time most of the larvae have dropped to the ground.

injury (figs. 5 and 31) is not, as a rule, serious; the larvae feed in the unfolding leaves, causing the "burned" appearance mentioned above. When pears are interplanted with prunes or are adjacent to them, the injury is generally more severe than in large contiguous pear plantings. The explanation is somewhat as follows: Other conditions being equal, the first adults emerging in the prune orchard find the buds insufficiently open (fig. 7); they then migrate to the pear buds, which can be penetrated, and join those adults emerging from

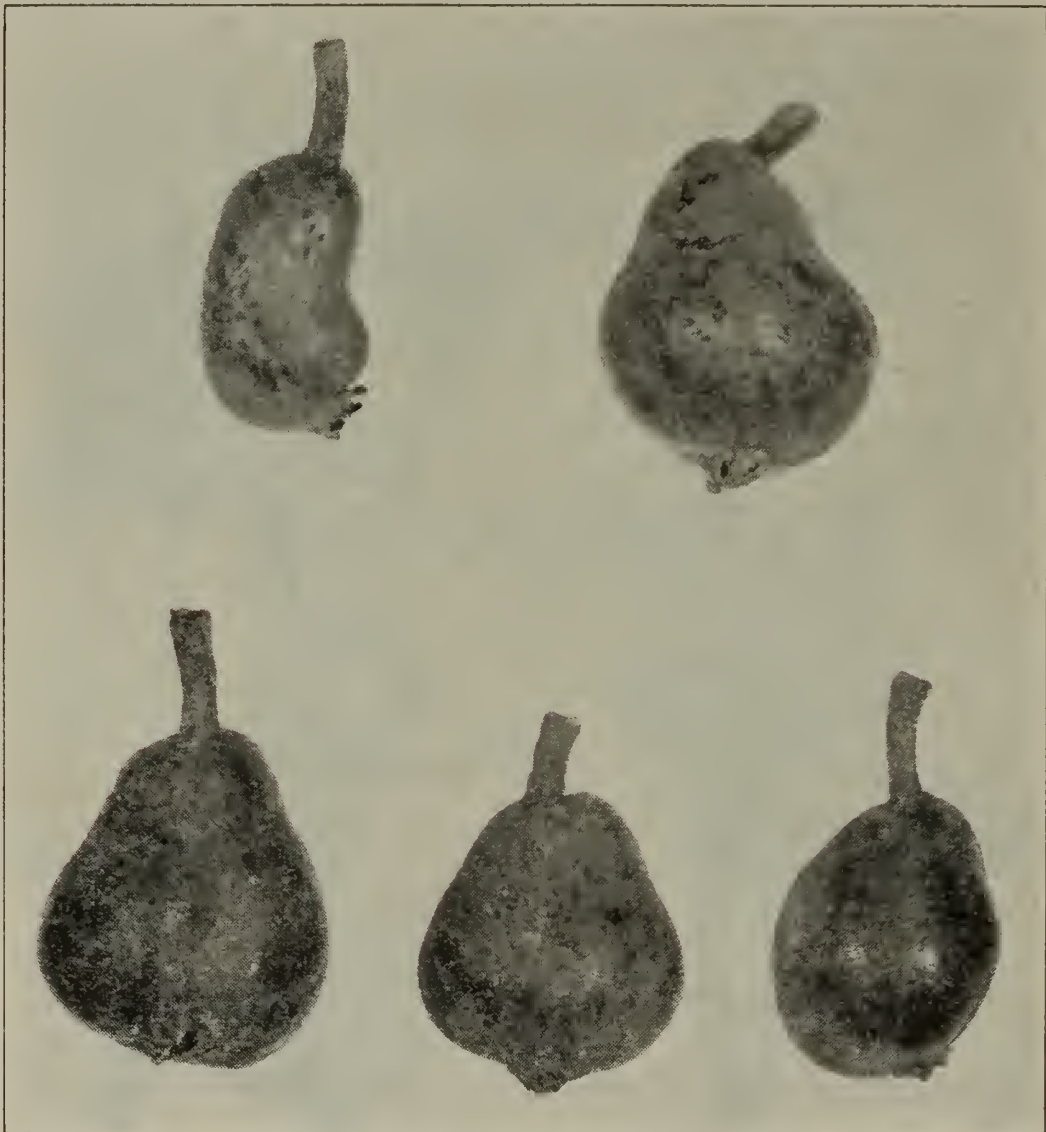

Fig. 6.—Pear-thrips injury to Bartlett pears. The short, scarred stems and the roughened, malformed appearance of the fruits are produced by the thrips larvae within about 2 weeks after full bloom. (From Cir. 346.)

beneath the pear trees. Later-emerging individuals find the prune buds sufficiently open, and there they remain. The result is severe pear-bud injury and a sustaining infestation (always greater in total numbers) in the prune orchard.

Injury to Prunes.—The bud damage to prunes is evidenced by a blackening of the inner faces of the multiple buds (fig. 8) and a shrivelling of the stems. Imperial prunes often fail to bloom when the buds are badly injured. The entire tree appears scorched; and the tiny leaves are blackened, so that the tree must put out additional leaves and thereby waste its vitality. During the jacket stage the larvae cluster on the fruit and cause blotches, swellings, and

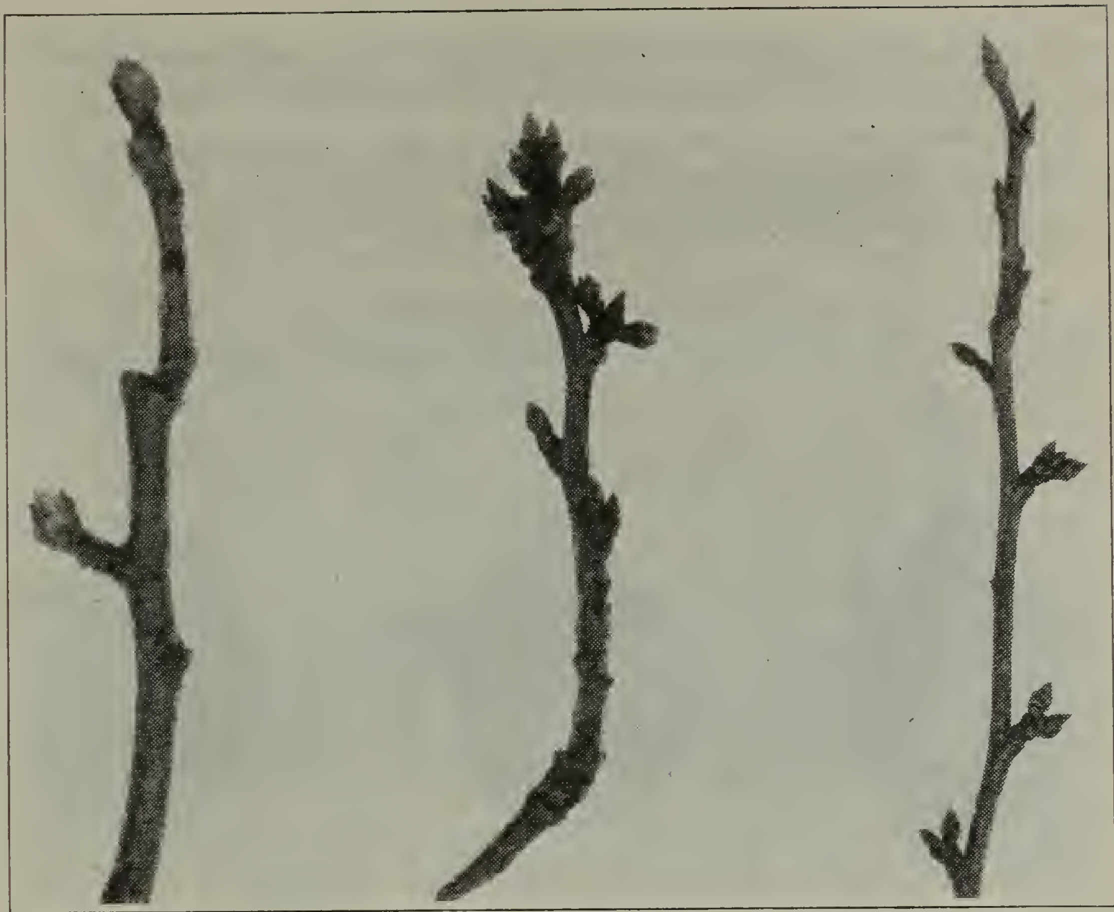

Fig. 7.—The Bartlett pear twig (left) illustrates the stage of development at which the first adult thrips enter the buds. At this time of year Imperial prune buds (center) are swelling and may be attacked, but French prune buds (right) cannot be penetrated by the thrips.

Fig. 8.—Injured fruit buds of prune, blackened on the stem and on the calyx. If severely injured by the adult thrips, they shrivel and drop (twig at left).

scars, which later expand and check as the fruit grows (fig. 9). Brown, leathery, and cracked areas are evident on the dried fruit. After the calyx falls from the fruit, the remaining larvae are found feeding on the younger leaves (fig. 10).

Injury to Cherries.—The cherry fruit itself is rarely injured by the thrips. The adults, however, lay large numbers of eggs in the fruit stems, thus causing considerable drop. Bud damage is negligible because of the natural stickiness of the bud scales and calyx lobes. As the leaves appear, the larvae cluster thickly thereon, killing them outright or causing a ragged, dwarfed condition (fig. 3), which later results in inadequate shade for the fruit.

Fig. 9.—Upper row, full-grown green prunes, showing the "scab" caused by the pear-thrips larvae during the "jacket" or calyx stage. Below are shown dried prunes, illustrating the blemished (light gray) areas caused by the thrips. Such fruit often results in as high as 50 per cent culls in badly infested orchards.

Injury to Other Fruits.—Other fruits that are attacked in California are rarely injured to any extent; almonds and apricots bloom before the peak of emergence, so that the larval populations are light. Apparently the fuzz on the small fruits of almonds and peaches is unattractive, and also the hairiness of apple buds. Nectarines, on the other hand, are severely scarred by the larvae.

DESCRIPTION

Technical and detailed descriptions of all stages have been given by Foster and Jones (1915). Priesner (1926), as well as Speyer and Parr (1941), has described and illustrated the larval stages.

The adult female pear thrips (frontispiece) is dark brown, slender, and

bluntly pointed at the posterior end. Newly emerged individuals are often light yellowish brown, but turn dark in a few days. The body is about $\frac{1}{16}$ inch long. The dusky, grayish wings, when not in use, project backwards, and are lighter near the base, resembling a light band in the center of the body.

The adult male pear thrips (fig. 11) occurs only in Europe. (In North America the eggs are not fertilized.) The male is smaller than the female, but has the same appearance.

The egg, too small to be seen without magnification, is white and bean shaped. Under a hand lens it appears as a minute swelling in the surface of the stems, leaves, and fruit.

Fig. 10.—"Burned" tips of leaves of French prune, caused by pear-thrips larvae. After the calyx falls from the fruit, the larvae feed on the unfolding leaves.

Upon hatching, the minute, translucent, white larva is about $\frac{1}{50}$ inch long. After a few days of feeding, it becomes chalk white and increases in size to about $\frac{1}{16}$ inch. When full grown it often takes on a yellowish cast, and the dark-red eyes become more pronounced. The distinctive ring of strong black or dark-brown spines, near the posterior end, separates this species from other thrips larvae (fig. 12).

The so-called "prepupal" and "pupal" stages (better known technically as the third and fourth nymphal instars) are delicate, white, and almost transparent, with dark-red eyes. They measure about $\frac{1}{20}$ inch and are more robust than the larva and adult. Wing pads are evident along the sides of the abdomen (fig. 12), and in the pupal stage the antennae are folded back over the head.

The male of *Taeniothrips inconsequens* was first recorded by Bagnall (1909), who wrote as follows:

An example of the male is amongst the specimens submitted to me by Mr. Collinge: it is much smaller than the female and the wings considerably over-reach the tip of the abdomen. Though countless specimens have been examined from the orchards of California, the male was never discovered, and this sex is therefore new to science.

In 1924 the same author stated:

Although I was able to record the hitherto unknown male of the pear thrips in 1909 I was unable to give a good description from the single example. Mr. Britten found a second male in May 1916 at Shotover, Oxon, whilst in May of this year I found many examples of this sex at Gibside, Co. Durham, and in Scotland, the females occurring in very great numbers on hawthorn and other plants. . . .

The sternites 3 to 7 possess a transverse-ovoid depression, whilst the 8th tergite is furnished with a long fine "comb" of mico-setae. The specialised series of tergite 9 comprise 6 somewhat long bristles, 4 on the posterior plane, those of the inner pair being more widely separated from those of the outer than from each other; the pair of the anterior plane are each situated on a line bisecting the space between the 1st and 2nd and 3rd and 4th bristles of the lower plane respectively. The distal series of setae on the upper vein of the fore-wing varies considerably.

Through the kindness of J. D. Hood, male specimens from Bagnall's collection have been studied, and this sex is herewith illustrated (fig. 11). The claws on the front tarsi are present, as in the female.

The pear thrips belongs to a large genus, *Taeniothrips,* including over a hundred species, with a world distribution. Priesner (1926), who reviewed this group in Europe, gives a key to the species; and Melis (1936) contributes additional descriptions. Steinweden (1933), reviewing the world species, divides them into four principal groups. *T. inconsequens* is readily separated from all others by the following characters: wings long and well developed, fore vein of fore wing with three to nine distal bristles; eyes strongly protruding; cheeks strongly arched; fore tarsus with strong terminal claw. Its distinct generic characters place it in the family Thripidae. The synonymy,[7] largely from Priesner (1926), is briefly given:

1895. *Physopus inconsequens* Uzel, Monographie der Ordnung Thysan. p. 117–119. (Published by the author.)
1904. *Euthrips pyri* Daniel, Ent. News **15**:294.
1909. *Euthrips inconsequens,* Bagnall, Jour. Econ. Biol. 4:4.
1912. *Physothrips inconsequens,* Karny, Zool. Ann. **4**:337.
1912. *Physothrips pyri,* Karny, Zool. Ann. 4:338.
1913. *Physopus pyri,* Reh, in Sorauer, Handb. Pflanzenkr. **3**:225.
1914. *Taeniothrips pyri,* Hood, Ent. Soc. Washington Proc. **16**:39.
1914. *Physothrips alpinus* Priesner, Wiener Ent. Ztg. **33**:191 (nec *alpinus* Karny).
1916. *Taeniothrips inconsequens,* Bagnall, Ann. Mag. Nat. Hist. (ser. 8) **17**:216.
1923. *Taeniothrips inconsequens,* Watson, Fla. Agr. Exp. Sta. Bul. **168**:41.
1933. *Taeniothrips inconsequens,* Steinweden, Amer. Ent. Soc. Trans. 59:269–271.

Other species of thrips found commonly in pear and prune orchards from February to May are the western flower thrips *Frankliniella occidentalis* (Perg.) and *F. moultoni* Hood, occasionally also *F. minuta* Moulton; the onion thrips, *Thrips tabaci* Lind.; the European grain thrips, *Limothrips angulicornis* Jablon.; and the predaceous thrips *Leptothrips mali* (Fitch), *Aeolo-*

[7] *Froggattothrips inconsequens* Bagnall, 1929, of Australia (Ent. Soc. London Trans. 77:176) is a distinct species belonging to the family Phlaeothripidae.

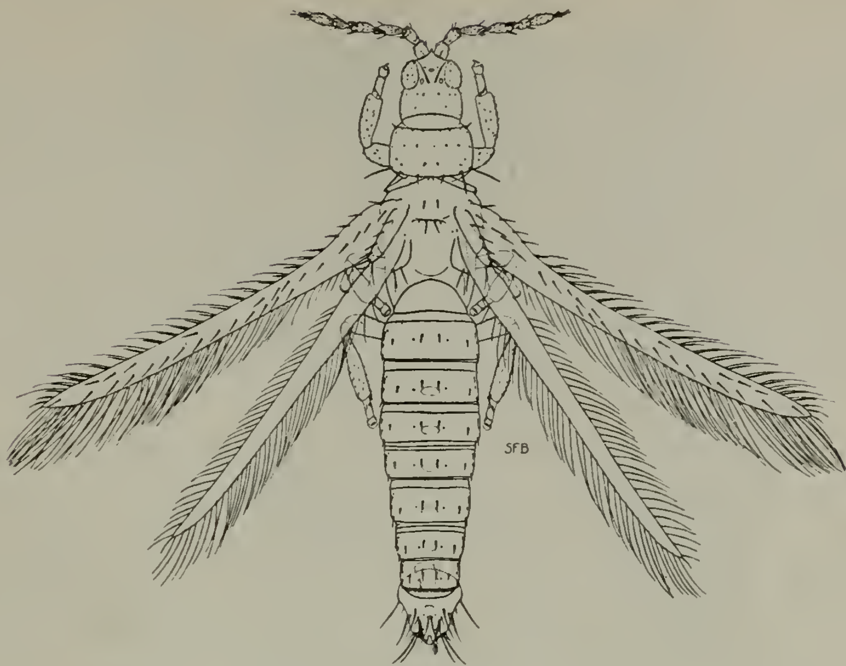

Fig. 11.—Adult male pear thrips, *Taeniothrips inconsequens* (Uzel), known only in Europe. Drawn from two specimens collected by R. S. Bagnall at Gibside, County Durham, England, in May, 1924. (Greatly enlarged.)

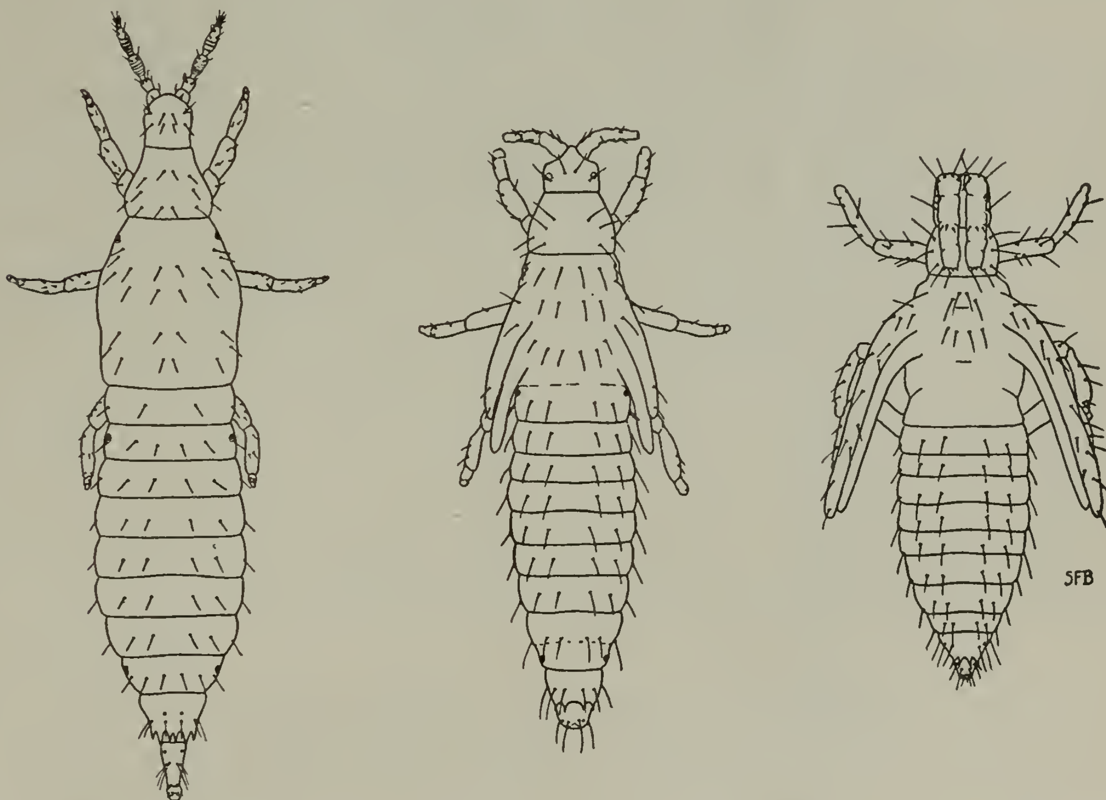

Fig. 12.—Immature stages of pear thrips, *Taeniothrips inconsequens* (Uzel). Left, mature larva; center, prepupa; right, pupa. (Greatly enlarged.)

thrips fasciatus L., and *Ae. kuwanaii* Moulton. Except the flower thrips, which are quite common in the blossoms, none of these species are abundant or destructive. Field identification is difficult; for accurate determination, specimens should be sent to a specialist.

TABLE 1

SEASONAL HISTORY OF PEAR THRIPS AT HEALDSBURG, CALIFORNIA, FOR THE TEN-YEAR PERIOD 1932–1941

Year	Total period of emergence	Days in emergence period	Peak of emergence	Full bloom of French prune	First larva on trees	Last larva on trees	First pupa in soil	First adult in soil	Degree of injury
1932	Feb. 19 to March 27	38	March 9	March 19	....	....	Oct. 15	Nov. 4	Very severe
1933	Feb. 16 to April 12	55	March 14	April 3	March 29	May 15	Oct. 4	Nov. 1	Very severe
1934	Jan. 30 to March 21	50	March 4	March 16	March 8	April 15	Oct. 1	Oct. 22	Moderate
1935	Feb. 18 to April 10	52	March 15	April 3	March 27	May 7	Oct. 16	Nov. 6	Light
1936	Feb. 23 to March 19	26	March 10	March 18	March 19	April 20	Oct. 23	Nov. 11	Negligible
1937	Feb. 19 to April 7	48	March 11	April 1	March 31	May 10	Oct. 15	Oct. 30	Moderate
1938	March 3 to March 30	27	March 14	April 2	March 30	May 4	Oct. 19	Nov. 4	Negligible
1939	March 1 to April 6	37	March 18	March 29	March 22	April 26	Oct. 23	Nov. 1	Moderate
1940	Feb. 24 to March 21	26	March 18	March 21	March 21	April 29	Oct. 28	Nov. 10	Light
1941	Feb. 21 to March 19	27	March 12	March 19	March 19	April 24	Oct. 27	Nov. 9	Negligible
Average	*Feb. 19 to March 28*	*38.6*	*March 12*	*March 25*	*March 23*	*April 30*	*Oct. 17*	*Nov. 4*	....

LIFE HISTORY AND HABITS

The life history of the pear thrips was outlined by Moulton (Moulton, 1905, 1907*a*; see also Howard, 1933). Later studies by Foster and Jones (1915) added much valuable detail, accurately gathered—the basis of our knowledge of this insect for nearly thirty years. Cameron and Treherne (1918), reporting from British Columbia, supplement the California studies and add many facts of value in interpreting the seasonal activities and ecology. In 1934 the writer published various ecological observations in relation to cultural control methods.

The findings of these writers, with other data gathered during the past ten years, are presented here. Although new facts will continue to be discovered, future workers may perhaps understand the cycles and the prediction of outbreaks better as a result of this study. The data were gathered largely in the prune and pear orchards of Sonoma and Solano counties from 1932 through 1942.

Habits of the Adult.—As soon as the fruit buds manifest activity in the spring, the adult thrips can be found within them. After passing the winter in the cell in the ground, the winged adult crawls and flies upward seeking suitable plant tissue upon which to feed.

The earliest emergence is usually in the lighter soil or better-drained portions of an orchard. A heavy covercrop holds back the emergence for a few days. The adults, if unable to enter the fruit buds, fly about and gather on willow, bay trees, ornamentals, and even manzanita. As the soil temperature rises, those thrips nearest the top of the ground emerge first. The earliest date of emergence on our records is January 11 (1934) in the Dry Creek district of Sonoma County, on California laurel. In the orchards, however, the first adults were trapped on January 30 of the same year. Normally in Sonoma, Napa, and Solano counties the emergence begins about February 20–25. In the Healdsburg area the average total period of emergence for 1932–1941 was February 19 to March 28, or 38.6 days. In 1933 the total was 55 days. The shortest period recorded was in 1936 and 1940, when the adults emerged for 26 days only. At this time (table 1) the peak of the emergence occurred on March 12—on an average, 13 days before the usual date of full bloom of the French prune (March 25).

The emergence data were gathered—with some modification—in the manner described by L. M. Smith (1933). The pyramid-shaped traps, 3 feet square at the base, were covered on the outside with roofing paper to shed water and to protect the cloth lining. Later, even more durable traps were made from plywood (fig. 13). The shell vials inserted in the hole at the peak of the trap were held in place by a shoulder in the retaining block or by fine screen wire tacked over the bottom of the hole. At regular intervals the vials were removed, and the thrips counted. A recording soil-temperature device was employed to determine when the emergence began and how long a covercrop delays the emergence.

Throughout five years, soil-temperature records were kept during the emergence. This experiment showed clearly that in heavy soil in the Suisun Valley the thrips began to emerge as soon as the soil temperature (at a 10-inch level)

reached 52° F for 2 or 3 days. Cold weather (and rain) slowed them down; but, in general, an emergence once started continued.

The adults have a remarkable ability to force their way up through the soil. Both the physical structure of the soil and its moisture content affect the emergence. Heavy soil poorly drained in wet years has a very low emergence in comparison with light, sandy soil. Spring floods do not, however, kill so many adults as does the continual puddling of the soil in prolonged rainy winters. Once the emergence has begun, the thrips will often come through flood water temporarily standing in the orchard. Normal winter rains have no effect: adults placed in vials of wet soil were observed to fold back their antennae and wings and worm their way through the cracks and openings

Fig. 13.—Emergence trap, constructed of oil-stained light plywood and reinforced with metal angle strips sturdily made to withstand several seasons' use.

in the clods. The tiny claws on the front legs appear to aid them in struggling upward through narrow openings. By spreading the wings they can readily float upon water, or extricate themselves from mud if not entirely submerged and trapped.

For oviposition the thrips apparently prefer deciduous fruit trees to any other hosts. Egg laying has been observed, however, on certain other trees and shrubs (see the section on hosts), but not on weeds or grasses.

Feeding begins as soon as the thrips locate succulent tissue in the buds. The mouth parts are constructed for rasping and sucking, and only the plant fluid is taken into the stomach. The scraping or rasping starts the flow of sap (bleeding), and the injured cells turn black or present the typical thrips scab. As many as 50 adults have been found in a pear bud, and 8 or 10 are often shaken from individual prune bud clusters.

Reproduction is by the egg laying of unmated females (Pussard-Radulesco, 1930), since no males are known to be present in North America. The rate of reproduction is therefore great, since an infestation can be started from one individual. Under favorable conditions, with all females reproducing, severe

injury will rapidly develop. The eggs are inserted beneath the epidermis by a small bivalved, swordlike blade or ovipositor with a toothed margin; a slit is made, and the egg passes downward between the plates of the ovipositor and into the plant.

Newly emerged adults rarely have any eggs visible in the body cavity. After a few days of feeding, however, eggs can be seen in mounted specimens. Laying begins a week or two after emergence, according to the weather and the rate of bud growth. The favorite place is in the fruit stems: as soon as the buds are sufficiently developed to expose the stems, the thrips can be seen inserting their eggs. Later-emerging adults begin ovipositing within about 3 days. Eggs are also left in the flower parts, the fruit, and the leaves.

Foster and Jones (1915), after detailed studies, reported: "The number of eggs that a female can deposit in a day is probably not over seven or eight, as the abdominal cavity is not large enough to hold more at one time." The maximum number known to have been laid by an individual is 155; and the maximum estimated number is 200. The average is between 75 and 100. As was mentioned above, egg laying begins in the so-called "green-bud" stage on prunes and the cluster-bud stage on pears and continues, in late-emerging females, until the petals are all off the trees. An average individual, however, lays for only about 2 weeks. The length of the adult pear thrips' life is 2 to 4 weeks.

Adults confined in cellophane bags in the orchard have lived on the average about 3 weeks; those living a month are among the earliest emerged and have been less active during the colder weather. In warm weather the adults rarely live more than 15 days.

A noteworthy habit is migration. In moderate infestations no migration occurs. As long as the adults find succulent tissue for feeding and egg laying, they fly about very little after reaching the trees. If, however, a severe infestation has browned and dried up the buds and blossoms, "swarming" does follow (Bailey, 1936). The movement out of the devastated orchard usually takes place in the afternoons of warm days. In such instances the thrips will get into the eyes, ears, and hair. Hundreds of adults have been collected on windshields and from light-colored clothes. A slight breeze will blow them readily, but in still air they fly irregularly from tree to tree. Such migrations are usually local, for only a few hundred yards, and their direction depends upon chance unless a prevailing breeze is blowing. Migrations take place only in epidemic years.

Egg Stage.—The length of the egg stage depends upon the temperature. In cool weather, hatching is delayed 16 or 17 days; and under ideal conditions of warm weather the minimum is 4 days. As other writers have pointed out, the eggs are not all in the same stage of development when they are laid; so, naturally, the incubation period is variable. In general the egg stage lasts 7 to 10 days; and since the emergence and the egg laying extend over 4 or even 5 weeks, it is often the end of April before the last eggs are hatched.

Habits of the Larva.—Immediately upon hatching, the minute, white larvae begin to feed on the stems, leaves, fruit, or flower parts. They prefer to be hidden or protected under the calyx, in small unfolding leaves, or on the underside of leaves. Their method of feeding on plant fluids is to rasp and

suck, like the adults. Their clustering causes localized spots or rings of scarred tissue on the fruit and stems, together with a cupped, ragged, or "shot-hole" appearance of the leaves.

The first larvae are usually found on willow, almonds, California laurel, or myrobalan plum seedlings. On such minor hosts the earliest that larvae have been observed was on March 7 (1941) at Fairfield. As shown by table 1, they are rarely seen on prunes until March 23, or about the time of full bloom. These forerunners of the major infestation are found on the sucker shoots on prunes and in or behind the calyx on pears. The larvae or "white thrips," as growers commonly call them, are present on the trees for a maximum of about 5 weeks (table 1); but in seasons of very cool weather a few can be found on the leaves till about May 15, or for a maximum of 8 weeks.

TABLE 2

LARVAL ACTIVITY IN A PRUNE ORCHARD, MARCH 15 TO APRIL 22, 1940, SUISUN VALLEY*

Date	Average number of larvae per cluster	Remarks	Date	Average number of larvae per cluster	Remarks
March 24	2.2	....	April 10	2.2	....
March 25–28	...	Heavy rain	April 11	2.6	Very warm
April 1	1.5	....	April 12	1.8	Very warm
April 2–3	...	Rain	April 13	1.6	Very warm
April 4	4.9	....	April 14	0.7	....
April 5	4.8	....	April 15	0.7	....
April 6	4.4	....	April 16	0.1	....
April 7	2.8	Light rain	April 18	0.08	....
April 8	2.4	Light rain	April 22	0.0	....
April 9	2.7	....	....	...	....

* Maximum, 38 days; peak, on April 4. Full bloom on March 20 (oil-sprayed trees March 15). Counts are based on 50 clusters.

The peak is commonly reached 7 to 10 days after the petals have fallen. Table 2, giving counts in an unsprayed prune orchard in 1940, well illustrates the trend of larval abundance.

The larvae migrate very little. They crawl about slowly and travel short distances over the leaf surface. Only when the leaves or fruit are entirely blackened (fig. 2) do the larvae move to adjacent twigs. At maturity, however, they are easily jarred from the leaves or blown off by strong winds.

The number per fruit or leaf cluster varies from tree to tree and still more widely on different kinds of fruit trees. The heaviest population is found on the Imperial prune, where, in severe cases, as many as 100 larvae may be shaken out of a single fruit cluster. Even greater numbers are sometimes found in leaf clusters on cherries. A moderate infestation on pears and prunes will yield 5 to 15 larvae per shake from each cluster, or about one third of the number obtained by picking the cluster apart. According to counts made from different levels, the greatest variation occurs in the treetops. Four hundred fruit-cluster counts made in 1939 on eight adjacent prune trees in the Suisun Valley averaged 3.97 per cluster, with an extreme variation of 0 to 16.

Only one molt, and this after 6 to 10 days of feeding, takes place on the trees. After shedding the first skin, the larva becomes much more robust and

shows a circle of dark-brown bristles near the posterior end of the abdomen (fig. 12). It feeds for another week or less, according to the weather. The feeding larval stage on the trees, therefore, lasts 15 to 20 days.

When mature the larvae stop feeding and lie on the leaves or fruit, or crawl about slowly. Many fall to the ground with the calyces that are shed. The remainder fall, are knocked off by rain, or are shaken loose by the wind. Rarely are they seen crawling downward on the tree trunk. Heavy rains beat

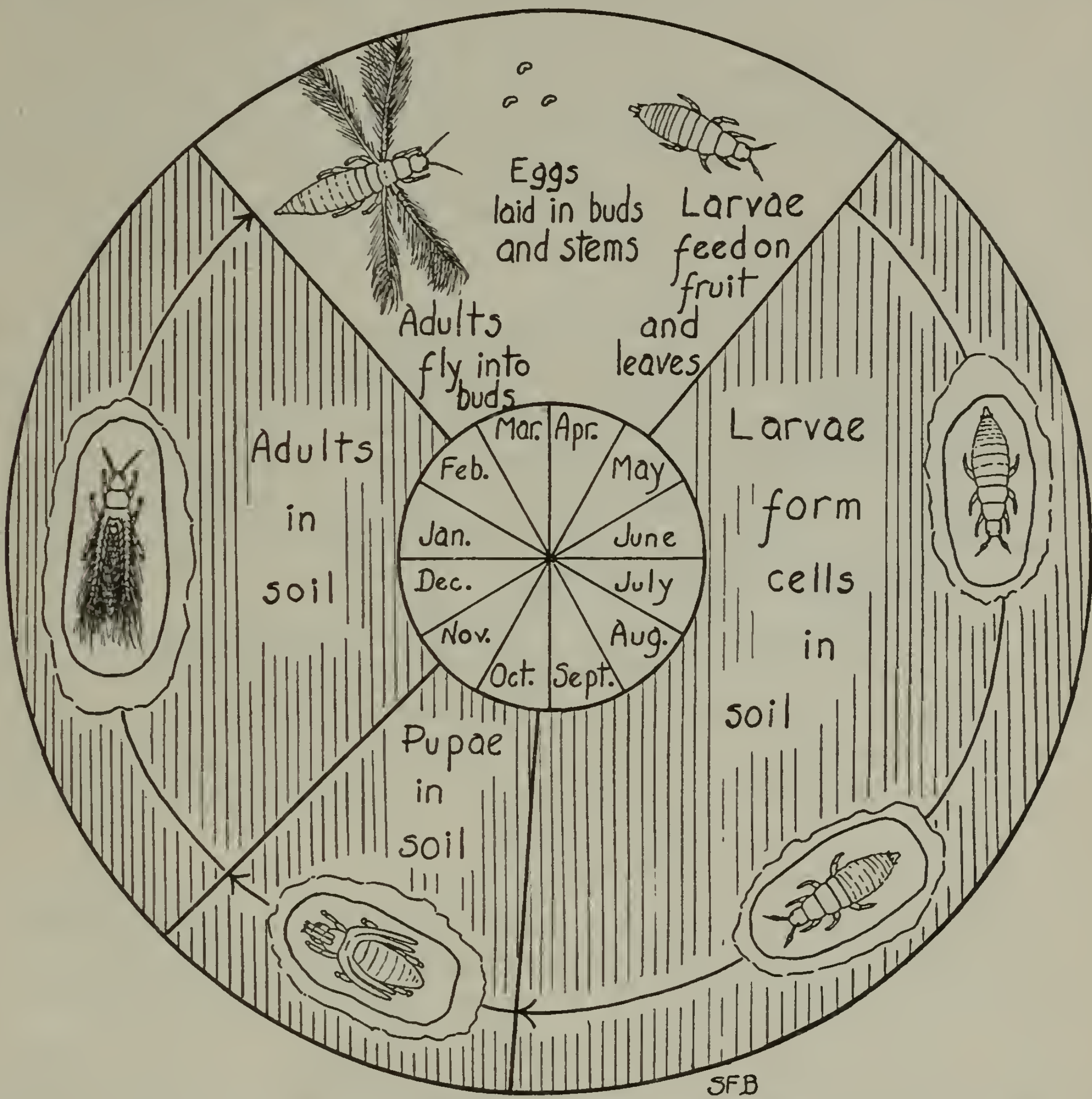

Fig. 14.—Seasonal cycle of the pear thrips.

off many of the immature larvae, which die if they find no weed growth on which to complete development.

After reaching the ground, which normally has been disked by the first of April, they crawl about over the clods and in a few minutes disappear. They utilize cracks, worm holes, old root channels, and the like in making their way downward to the plow sole or to soil undisturbed by the plow. Very few remain within 5 inches of the surface (fig. 24); those that do, gradually succumb during the summer as the soil dries out (fig. 15). The depth of plowing and the soil type largely influence the depth to which larvae penetrate. In tightly packed clay or gravelly soils they seldom occur below 10 inches, whereas in the porous, sedimentary soils along the Russian River they are found as deep as 2 feet, the majority being located between 6 and

12 inches. In El Dorado County, where permanent covercrops (or sod) are commonly maintained, the larvae are found 3 to 6 inches below the surface.

Over 90 per cent of the population remains in the soil directly under the trees, for there is little lateral movement in soil before the cells are made. Sections of plywood were placed over marked areas beneath prune trees during the larval period to exclude them. The following spring, emergence traps placed over these areas caught no thrips. Clearly, therefore, the larvae remain within a short distance, probably less than a foot, from where they drop.

After finding a suitable niche, the larva constructs its cell (fig. 14) very simply by turning around and around, smoothing the inner surface with the tip of the abdomen. The heavy spines assist in this work and also in fending off other larvae when crowding occurs. The cell is large enough for its occupant to turn around in easily; and the rule is only one larva to a cell, although larvae sometimes cluster in small clods.

Their abundance is shown by Foster and Jones (1915), who found a maximum of 1,725 in a square foot of soil. In recent studies the greatest concentration encountered was in the spring of 1934 in Dublin loam soil near Windsor (Sonoma County), when 1,200 adults emerged from one square yard. Emergence traps placed in the center of the tree row between four trees catch practically no thrips, since more than 90 per cent of the population carries over beneath the drip of the trees.

During April and May, when the cells are formed, considerable moisture is present. As the soil dries out, the cell hardens, sealing the larva within. Sandy or gravelly soil, however, crumbles away as the moisture evaporates; and thus the larva, unable to form a new cell from the dry particles, becomes desiccated. An individual will fashion a new cell many times if disturbed or removed, provided the soil is moist enough.

There is some natural mortality, up to 50 per cent; but conditions vary so greatly that the actual figure is hard to determine. Larvae occasionally fail to hatch if the tissue in which the eggs are embedded shrivels or dries, as in severe injury to the plant. On the trees, predaceous insects such as ladybird beetles and thrips, as well as spiders, consume a few, but make little impression on the population. As already mentioned, a heavy spring rain will dislodge many partly grown larvae from the trees; and they will then starve if no weeds are present, since they cannot crawl back up. Exceptionally heavy rains at this time also beat many of the larvae into the top soil, puddling and drowning them before they can penetrate downward and form cells. In years when the soil moisture remains high all summer, larvae die in their cells, although normally irrigation has little effect upon them. Moulton (1907*a*, 1909) believed that a fungus attacked them and caused death. In the writer's opinion, however, the larvae die from prolonged contact with excessive moisture, and the fungus attacks them afterward. In no type of soil do the larvae survive the summer within 5 inches of the surface in cultivated orchards. As the soil-surface temperature increases and the moisture decreases, they become desiccated. In young orchards, especially pear orchards in contrast to prune, the soil is less well shaded, and there is consequently a greater mortality from this cause.

Habits of the Pupa.—Under normal conditions the larvae remain in their cells from early May till October, when they molt to the so-called "prepupal" stage. Other entomologists have noted pupae as early as May; and in 1934, after a very rainy cool period, the writer found pupae at Healdsburg on June 8. These unseasonably developed forms do not survive, as nearly as could be determined.

Transformation to the pupal stage is induced by lowered soil temperature and increased soil moisture. Of the two factors, temperature appears more important. When the larvae were placed in a cool room (60° F or lower), pupation was brought about artificially in a minimum of 43 days from the time they left the trees. Pupae have transformed to adults as early as May 21 in jars of soil in cold chambers.

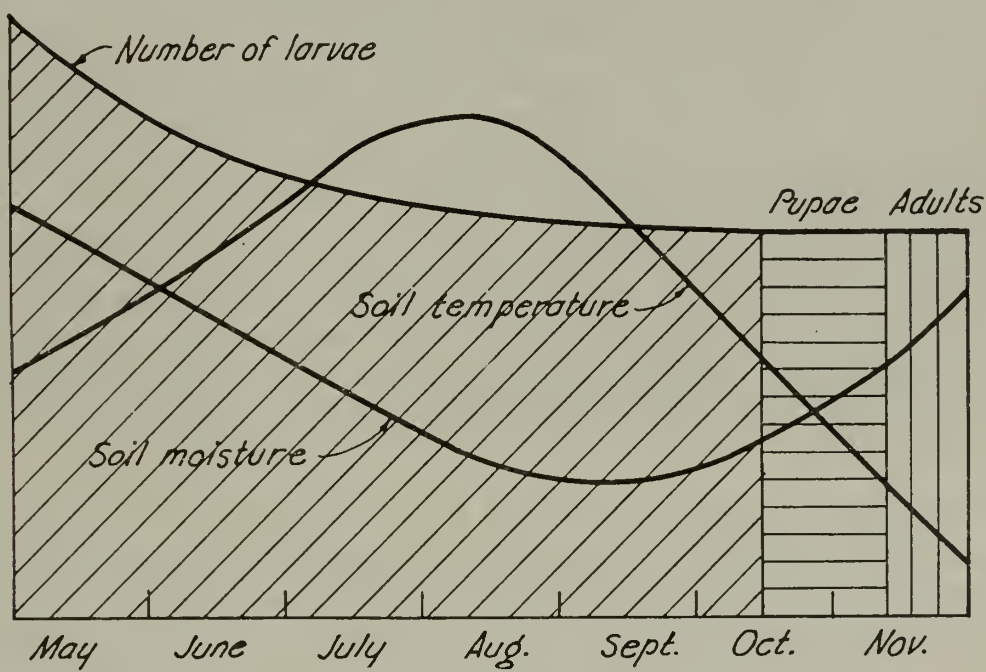

Fig. 15.—Diagram to illustrate transformation of pear thrips in soil in relation to soil temperature and moisture. As the soil dries out and its temperature rises, the thrips larvae within about 5 inches of the surface die. In the fall the cooler temperature and the increase in moisture stimulate the transformation to the pupal stage.

From 2 to 7 days is spent in the first pupal stage. Then, after another molt, the insect assumes the second pupal stage. This period averages 7 days (with a range of 7 to 15 days), making the total pupal period about 2 weeks for each individual.

The season of pupation lasts about 4 weeks, individuals in the heavier, better-shaded portions transforming first and those in the warmer, drier area last, with gradations between. The variation in widely separated districts and counties is even greater. According to records kept in the same orchard (see table 1), for ten years, the average date of pupation was October 17, with a variation of 4 weeks from October 1 (1934) to October 28 (1940). The maximum number of pupae are present about the last week in October and the first week in November in the average season in medium to heavy soils in Solano, Napa, and Sonoma counties. When the fall is dry and very warm, larvae and pupae have been found as late as December 20 (1934) in pear orchards of Solano County.

The pupa transforms to the adult stage (by means of another molt) almost always within 2 weeks, and adults may be found in the cells from about October 22 on. Foster and Jones (1915) noted pupae in July, August, and September, but never any adults. The present writer has not seen adults in the field before October (fig. 15).

The pupal stages are delicate—easily injured or drowned. Excessively heavy fall rains (or irrigation), thoroughly wetting the soil down to about 12 inches, produce a high mortality. Pupae are negatively phototropic and crawl away from the light if their cells are broken open. They cannot form a new cell. The newly transformed adult, yellowish brown, also shuns the light and will not feed or form a cell.

Seasonal Cycle.—There is only one generation or brood each season, and 9 to 10 months is spent in the soil under the host plants.

Emergence begins the last of February and continues 3 to 6 weeks, according to the temperature. In the San Francisco Bay counties the seasonal peak of emergence is reached during the first 2 weeks of March; at higher altitudes and northward, somewhat later. The adults attack the swelling buds of fruit trees and begin egg laying in early March.

By full bloom most of the adults have disappeared, and the eggs begin to hatch. The larvae appear in maximum numbers during the first 2 weeks in April. After feeding 2 weeks or longer, they drop to the ground. By the first of May the pear thrips has disappeared from the trees until the following spring. In the Sierra Nevada counties the sequence of events is 2 to 4 weeks later.

The mature larvae penetrate the soil 6 to 15 inches and there form a rough cell from the soil particles. Some natural mortality takes place during the summer. As the soil temperature drops and the moisture increases, the survivors are stimulated to pupate (fig. 15). In late October and early November this transformation occurs. The pupation season covers about a month, according to the depth of the thrips and the amount of soil moisture. The pupae change to adults normally in November. Thereafter the adults remain in the cells until the soil warms up in the following spring and they are stimulated to seek the trees, thus completing their annual cycle.

FACTORS AFFECTING ABUNDANCE OF THRIPS AND CYCLIC TENDENCY OF OUTBREAKS

After the initial outbreak of pear thrips in the Santa Clara Valley, 1904–1911, the infestation dropped noticeably. For about nine years, 1912–1920, there were no serious epidemics. After a minor outbreak during 1921–1923, the thrips population dropped to a low ebb again until 1929, when the greatest and most widespread infestation took place. Naturally investigators have sought the cause of such outbreaks and a method of predicting them.

Early workers knew that weather and soil conditions greatly affect the abundance of the pest (Ehrhorn, 1907); but the data on this relatively new insect were insufficient to justify conclusions. Clarke (1913) wrote of conditions in New York as follows:

> An examination of infested orchards at Coeymans Hollow, at Germantown and at Hudson showed that without exception the injury occurred on a heavy soil where early and thorough

cultivation was presumably difficult or impossible. The pear thrips appears to be absent from orchards on the lighter, sandy soil of Kinderhook.

Foster and Jones (1915) definitely showed that the population is much greater in sedimentary or loamy soil, in which the larvae can penetrate deeper, than in clay or gravel, which packs harder and forces them to remain nearer the surface. As these writers also realized, heavy spring rains reduce the population on the trees, and abnormally dry conditions in fall are unfavorable to pupation.

Essig (1920) summarized the conditions very well:

The appearance of the pear thrips in the orchards is sporadic; no two successive seasons are alike in any particular locality. It becomes destructive in small or in large, widely separated areas and may be very unevenly distributed in these. It is seldom that a large body of contiguous orchards is found uniformly infested; there may be a small district here, an orchard there, or a number of orchards having serious outbreaks, while neighboring trees escape injury. It is true that some individual insects may be found in practically all orchards, but in many they are not found in sufficient numbers to injure the crop. This fact has not been entirely explained, but the chief factors responsible therefor probably are climatic conditions, general orchard practices, artificial control, and natural enemies. . . .

No rules or regulations based on climate can be formulated to determine in advance the abundance or destructiveness of pear thrips because little is known respecting just how much this insect is influenced by rains or droughts, and by cold or hot weather, but from the past observations the extreme of any of these over a period of several years has a noticeably detrimental influence on development; while under what appear to be the climatic conditions most unfavorable for thrips, some sections are seriously affected. In commercial fruit growing it is not a safe practice to rely upon any extreme of climate to control the insect.

Lovett (1921), discussing the history of the pest in North America, wrote as follows:

In all of these areas there has been a marked variation in the severity of attack in succeeding years. As a rule, there is a period of years, early in the infestation, when the destruction, some seasons, is very heavy, resulting in a total loss of the crop. There is a tendency for the wholesale destructiveness to lessen after a period of years of heavy losses.

In British Columbia also, climatic factors appear definitely to affect the distribution and abundance of the thrips from year to year.

L. M. Smith (1933) clearly demonstrated that a much greater emergence (averaging about six times as great) took place from heavy soils than from light soils. His observations were made, however, during a very dry season.

Sufficient data have now been gathered from the records of older workers and growers, as well as from recently compiled information, to give a better perspective and understanding of the cycles than has been possible heretofore.

The writer has previously (1934) pointed out the main factors influencing abundance, especially cultural practices and other special conditions that affect local infestations. It now seems possible to survey the outbreaks in the state as a whole and the weather conditions that apparently influence them.

First, perhaps, one should compare the climatic conditions of the fruit-growing areas of the interior valleys with the infested areas nearer the coast, in order to ascertain the optimum conditions for maintenance of the insect. Climographs of selected points (fig. 16), in comparison with the known distribution, bring out the following facts: In the Sacramento Valley the monthly mean temperature for July and August in the fruit-growing areas is about 75° F or above. As has been reported (Bailey, 1934), the larval mortality in

laboratory studies (using the Yolo series of soil) is very high if the soil moisture drops below 9 per cent (figs. 24, 25, 26). The mortality increases, furthermore, in direct proportion to the increase in temperature (fig. 28); in soil of an optimum moisture content (about 12 to 14 per cent; see fig. 25), 100 per cent mortality occurs at 100° F. Soil-surface temperatures (½ inch depth) are often as high as 140° F on bare soil. On extremely hot days (July 17, 1925,

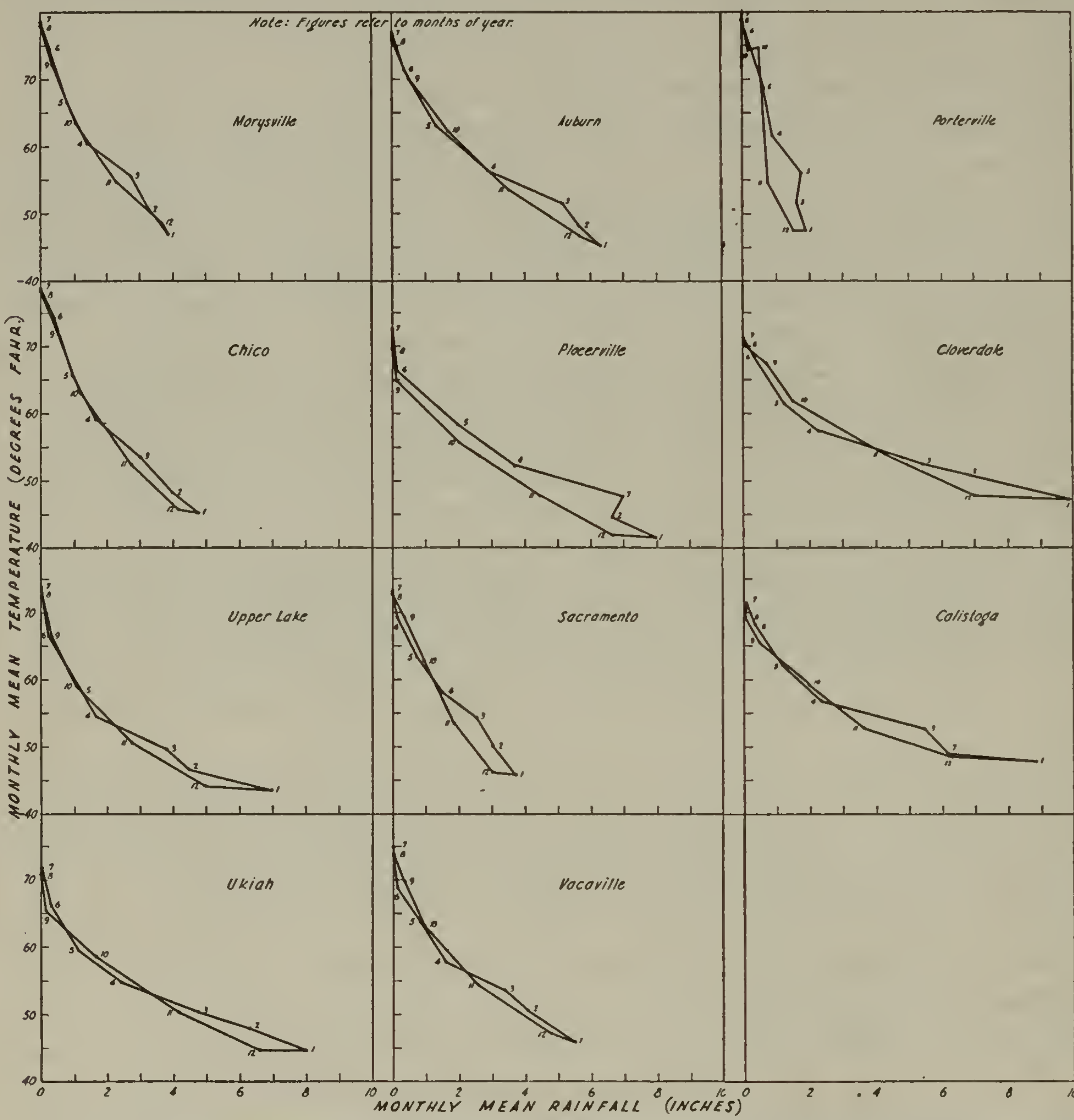

Fig. 16.—Climographs of selected deciduous-fruit-growing areas in northern California to illustrate limiting climatic factors in the distribution and relative abundance of the pear thrips.

at Davis, for example) with a maximum air temperature of 117° F, the maximum soil temperature was 101° F at the 6-inch level, and 93° F at 12 inches (A. Smith, 1927, 1929). In prune or pear orchards the relative area of ground shaded varies naturally with the time of day; and the average temperatures would be lower than on bare soil, especially around the tree trunks. Obviously, if exposed to average summer temperatures in these areas (see climographs of Chico, Marysville, and Sacramento, fig. 16), very few thrips would survive. There are, however, minor exceptions. The local infestation east of Marysville (Dantoni) occurs on a heavy clay soil (volcanic ash) having a high water table, in a place where large trees cast a heavy shade. Even under these conditions the population is low and maintains itself only in local spots

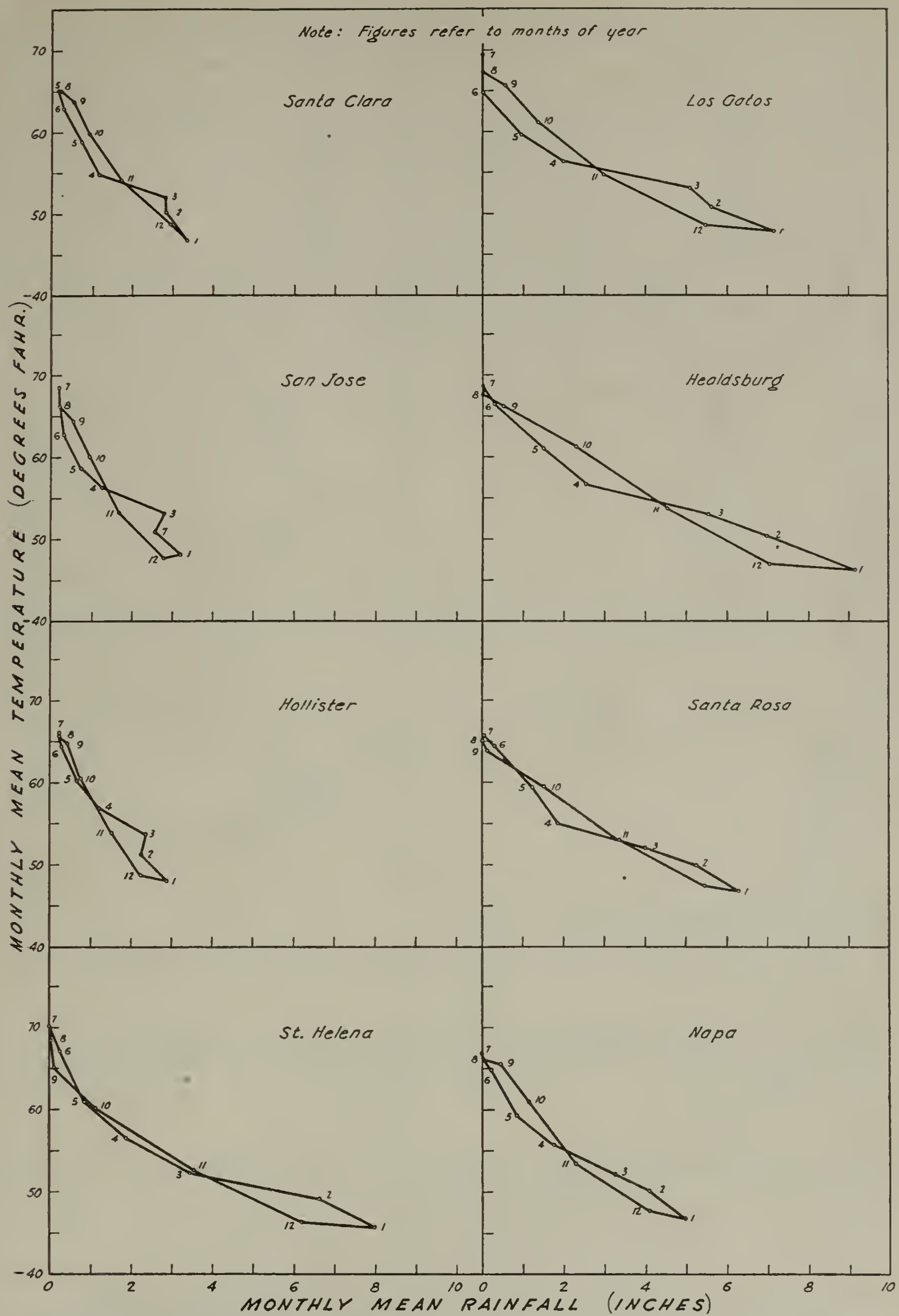

Fig. 17.—Climographs of selected deciduous-fruit-growing areas in central California that present optimum climatic conditions for the pear thrips.

within the orchard. At Vacaville and Auburn (fig. 16), on the edge of the valley, the infestations are marginal, surviving locally only in irrigated orchards on the heavier soil. Along the lower Sacramento River a high water table also obtains; and here also a minor population is maintained.

In the San Joaquin Valley prune-growing districts, such as Visalia and Porterville, the temperatures are much higher (fig. 16); and, in addition, the sandy soil makes construction of the protective earthen cell almost impossible.

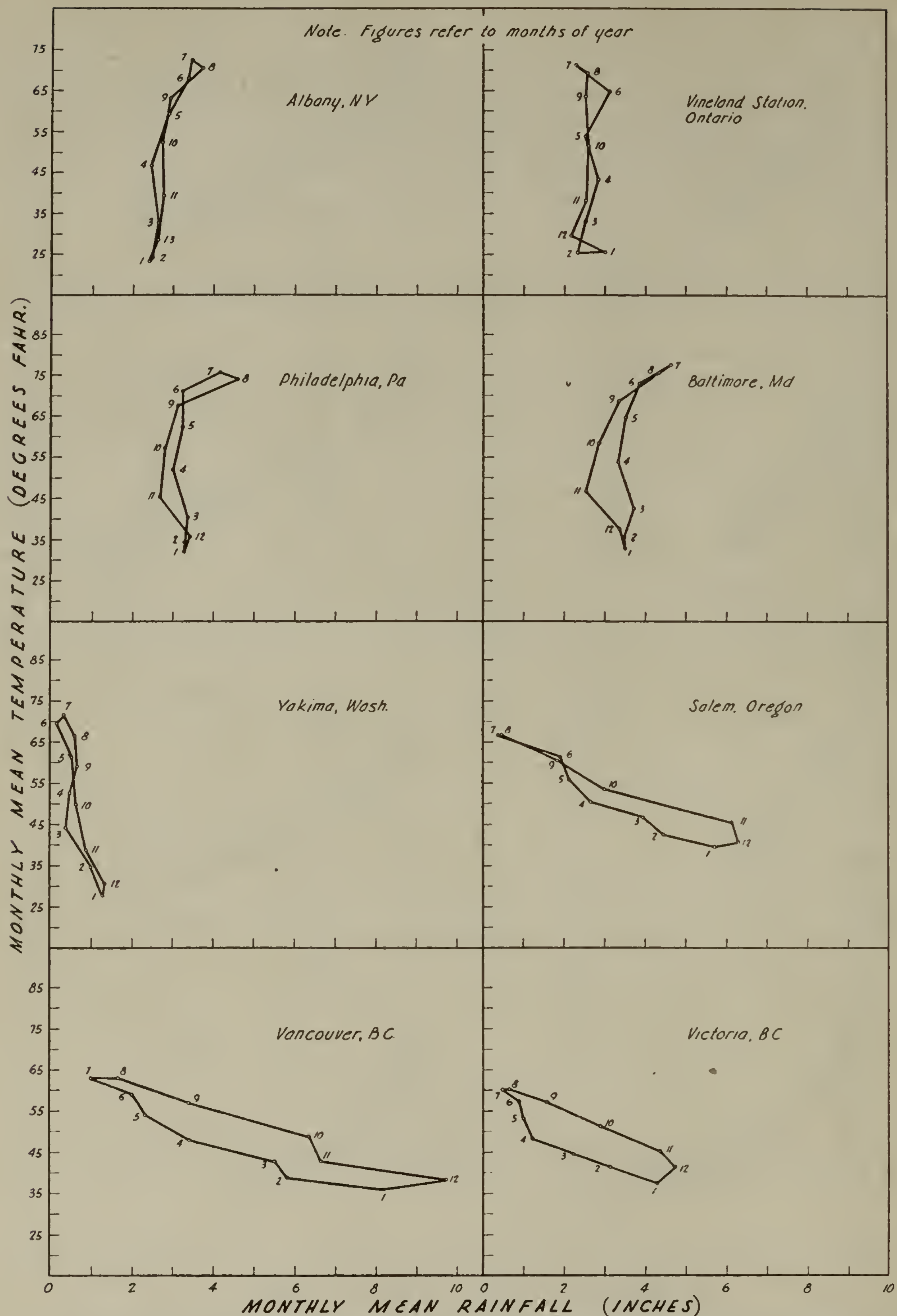

Fig. 18.—Climographs of selected areas in North America to illustrate climatic factors limiting the distribution of the pear thrips.

In other areas (not in the principal valleys), where the monthly mean temperatures for July and August are below 75° F, serious injury occurs only in epidemic years. Such districts are Ukiah, Lakeport (see climograph of Upper Lake), Cloverdale, Calistoga, and Placerville (fig. 16), where the critical rainfall (April–October) is higher and, together with the high summer soil temperatures, acts as a limiting factor. In these areas the population decreases noticeably in wet years (figs. 20, 22). The Placerville area is an

exception in one respect, since the permanent covercrops maintained in many orchards have altered the soil conditions. Here, as in all areas throughout the distribution of the insect in California, the greatest population survives in low, moist areas in dry, hot seasons and, conversely, in the higher, better-drained portions of the orchards in wet seasons.

The optimum conditions for the pear thrips appear to be found in the prune-growing areas of the lower Napa and Sonoma valleys, the Suisun Valley, the Santa Rosa district, and the Santa Clara Valley. According to climographs of these localities (fig. 17), the monthly mean temperatures for July and August are near 65° F. Some local orchards in these areas exhibit injury

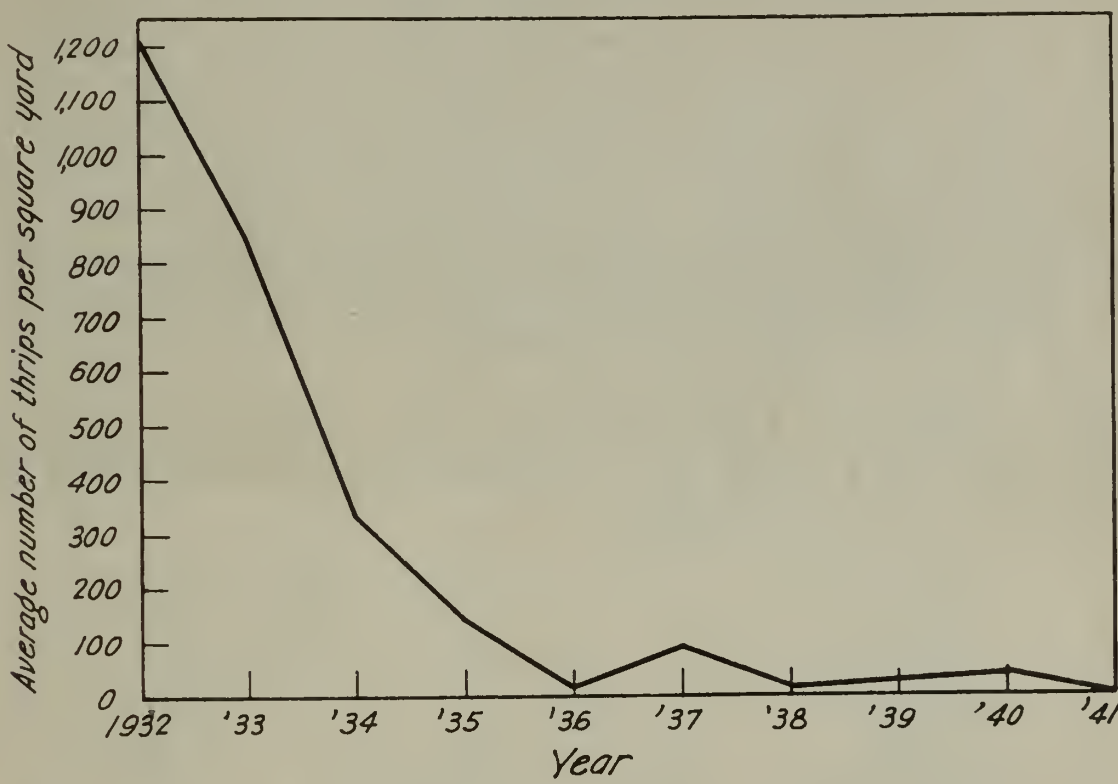

Fig. 19.—Abundance of pear thrips, Sonoma County, California. The adults were caught in emergence traps in the same orchards each year; and the average number per trap, which covered 1 square yard of soil surface, was ascertained to show the yearly trend in the infestation.

annually. The rainfall is higher in Sonoma and Napa counties, progressively northward; and—in dry years chiefly—the Saint Helena, Healdsburg, and Geyserville districts are subjected to considerable losses.

In comparison with the West Coast the eastern states, notably New York, have not suffered severely from the pear thrips. Climographs of Albany, New York, Baltimore, Maryland, and Vineland Station, Ontario (fig. 18), show a consistent summer rainfall, which is absent in the West (see climograph of Yakima, Washington). Irrigation, however, can replace some of this normal rainfall. Most of the eastern localities where the thrips is found do not regularly have summer temperatures above 100° F to act as a limiting factor.

In central and western Oregon and Washington, as well as in British Columbia (fig. 18), the mean summer temperature in the pear- or prune-growing districts is not above 75° F. In the eastern portion of these states the hot, dry summer season limits the thrips. The rainfall near the coast, however, is much greater. Variations in rainfall and their effect on thrips

abundance are best exemplified in British Columbia. On the Saanich Peninsula of Vancouver Island, where the thrips is an economic problem, the climograph (of Victoria, B.C.) shows a prevailing climate similar to Santa Clara, California. On the other hand, the rainfall a few miles away on the mainland (Vancouver) is much higher. The thrips is never a pest near Vancouver.

These data would indicate that (within the distribution of the insect) rainfall has a greater influence on abundance than does temperature. The annual total rainfall is not important in comparison with the time of year when heavy rains occur. At two critical periods in the seasonal cycle of the thrips, rains are very detrimental: in the spring, when the larvae are on the trees and are dropping to the ground to form their cells; and again in the fall, when pupation occurs. In studying the effect of rainfall on the "cycles" of the pear thrips one sees, therefore, that the best index of potential soil population is not the total seasonal precipitation, but the amount of rain received in April, May, September, and October. This method gives a fairly good general picture of what to expect the following season; but wide local differences in rainfall, soil types, and cultural practices present exceptions, so that the critical amount of rainfall in different districts will vary.

Judging from a detailed study of the history of the pest in Healdsburg, 6 inches of rainfall from April to November is the critical level. In the accompanying graphs (figs. 20, 21, 22) the degree of injury has been arbitrarily designated by numerals as follows:

None	0
Negligible	1
Slight	2
Moderate	3
Severe	4
Very severe	5

The annual degree of injury was then plotted against the amount of critical rainfall. The population as shown in the trap record (fig. 19) follows the same trend as the estimated degree of injury for Sonoma County (fig. 20). Since trap records over a long period of years from various localities are unavailable, this method is convenient for correlating the degree of injury with the rainfall, which is the major factor influencing epidemics.

A similar graph for San Jose (fig. 21) is presented. At Placerville (fig. 22) the critical rainfall seems to be about 9 inches. When a high rainfall occurs in April and May, the reduction in the amount of scarred fruit shows up the same season, whereas heavy rains in the early fall reduce the overwintering population, and bud injury the following spring. The injury curve may lag, therefore, behind the critical rainfall, as in 1934 and 1935 (fig. 20).

On the whole, thrips are much worse in dry seasons—not only the injurious species, but thrips in general. In dry years, species of *Frankliniella, Taeniothrips, Seriocothrips, Heterothrips, Aeolothrips, Erythrothrips,* and *Ankothrips* are abundant on the native vegetation.

It is safe to predict that a dry fall, followed by an early, dry spring, will offer favorable conditions for serious thrips infestation.

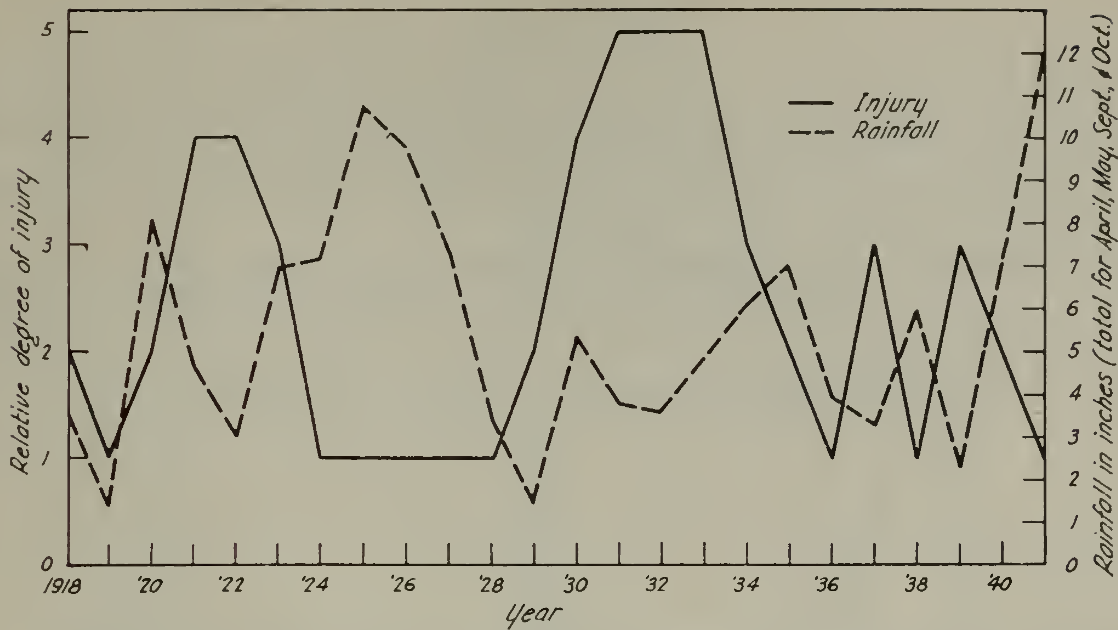

Fig. 20.—The relative degree of injury by thrips at Healdsburg was plotted against the rainfall for April, May, September, and October. As the total rainfall for these months reaches 6 inches or more, the injury drops. This method serves as a fair index for the expected infestation the following spring. (For definition of degrees of injury, see p. 32.)

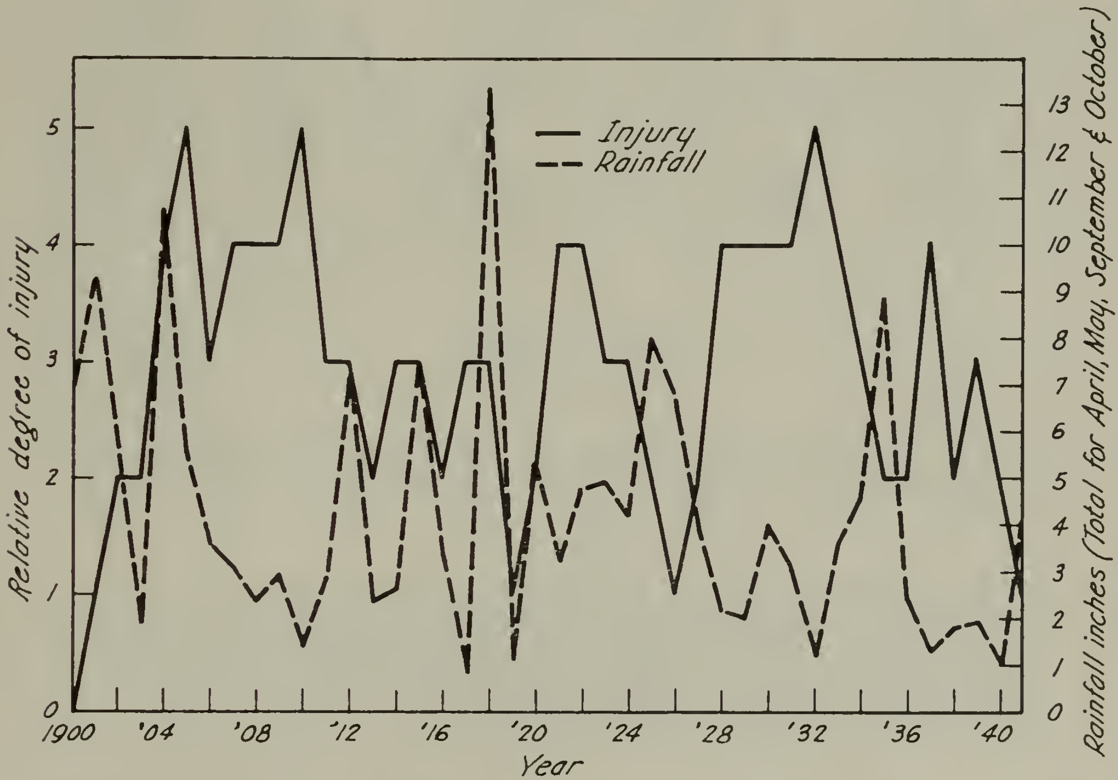

Fig. 21.—The critical rainfall for the San Jose area, as for Healdsburg, appears to be about 6 inches; but, since the normal rainfall in this area is much lower than at Healdsburg (see fig. 20), a higher thrips-population level is maintained, and the correlation is less pronounced. (For definition of degrees of injury, see p. 32.)

NATURAL ENEMIES

The pear thrips has very few natural enemies, and no important ones. The tiny wasp *Thripoctenus russelli* Cwfd., a common parasite of the bean thrips, onion thrips, and others, has never been observed to attack *Taeniothrips inconsequens*. Ladybird beetles are not usually out of hibernation in sufficient

numbers in April to serve as predators. Various spiders attack the thrips, but are rarely present in any number; the same is true of predaceous insects, particularly *Triphleps* spp., *Aeolothrips kuwanaii* Moulton, *Ae. fasciatus* L., *Podabrus* sp., lacewings, and *Raphidia* sp. Birds are apparently not interested in using the tiny thrips for food. The total effect of all these enemies of the adults and larvae on the trees is negligible.

In the soil there are practically no enemies of the larva, pupa, or adult, the greatest adverse influence being the weather. Moulton (1907*a*) reported a

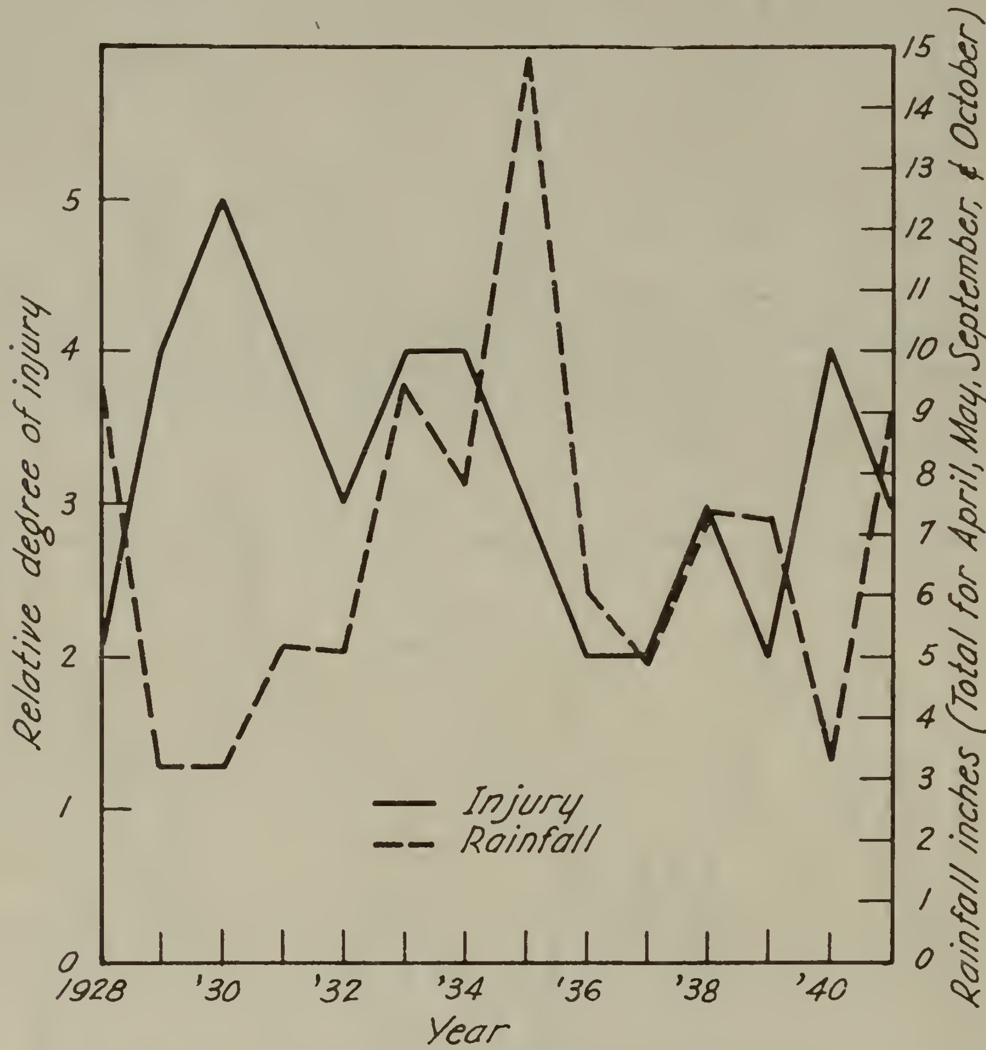

Fig. 22.—Information on the thrips injury at Placerville is not extensive; but the same trend is followed as at Healdsburg and San Jose—that is, when the total rainfall for the critical period is high (in this locality about 9 inches), the degree of injury is slight. (For definition of degrees of injury, see p. 32.)

fungus *Cladosporium* sp. as attacking the adults on the tree and the larva in the ground in 1905 and 1906; but Foster and Jones (1915) later wrote: "The last three or four years have failed to show that any appreciable amount of benefit has been derived from it." Over a period of eleven seasons the writer, examining many orchards and thousands of pear thrips, has come to believe that the fungus attacks only the thrips that have died from some other cause. The greatest enemy of the pear thrips is excessive rainfall or continued high soil moisture.

CONTROL

Among various species of thrips attacking crops, the pear thrips is especially difficult to control, mainly because of its concentrated activity in the spring and the irregularity of epidemics. Its small size and its habit of creeping under the bud scales of host plants have hampered successful spraying. Cultural control measures have been tried with varying success and are mainly supplementary; they have definite limitations.

Cultural Control.—The growing of heavy covercrops has been advocated to produce unfavorable soil conditions during emergence as well as to delay the emergence until after full bloom. L. M. Smith (1933) showed that a heavy

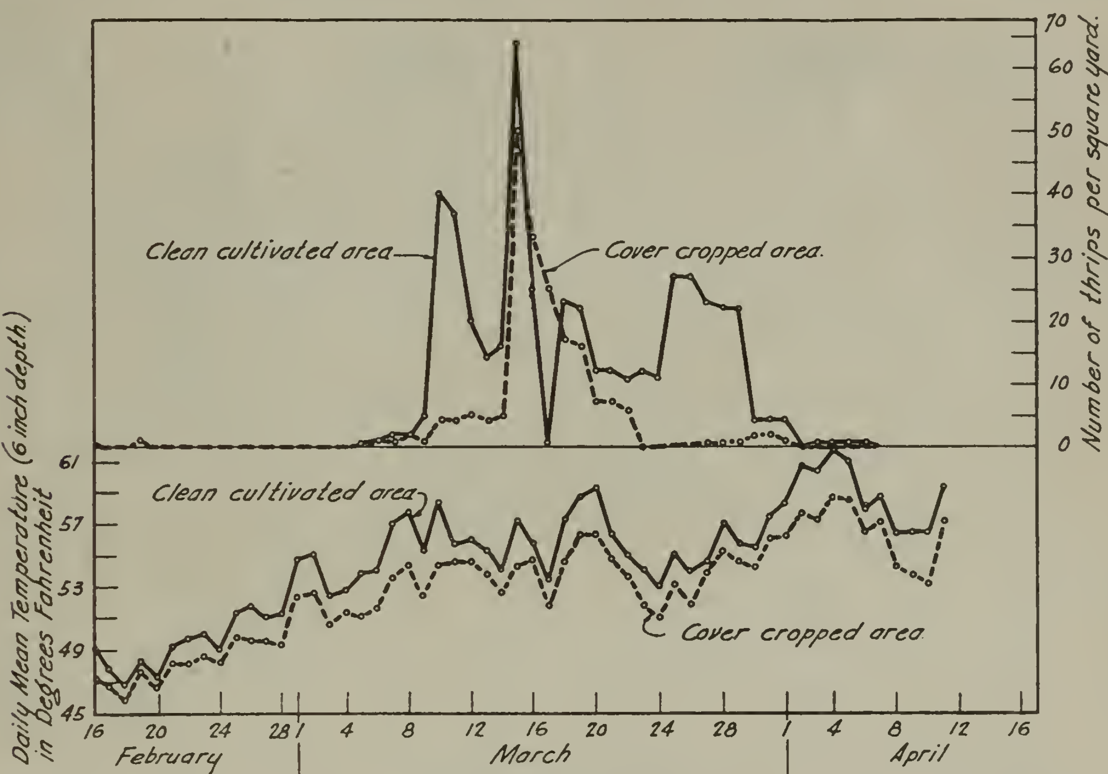

Fig. 23.—The results of a covercropping experiment to delay or reduce the emergence of the pear thrips are represented graphically. (Healdsburg, 1933.)

covercrop retarded emergence up to March 2 (1932) only. The peak of emergence did not occur, however, until a week later. Even though the adults remained on the covercrop for a few days before flying to the trees, the retarding effect was unimportant for bud injury, since full bloom did not take place until March 19 (table 1). In 1933 the writer experimented with a recording soil thermometer. The temperatures at a 6-inch level under a heavy vetch covercrop and on bare soil were recorded and correlated with the trap record from each area (fig. 23). The average temperature beneath the covercrop proved to be only about 3 degrees lower than at the same depth in bare soil. The emergence from the covercrop lagged behind that from bare soil, but the peak was reached at the same time in both areas. Naturally the bare soil showed a greater fluctuation in temperature. Total emergence from the covercropped area was much less than from the bare soil.

In addition to this experiment, soil-temperature records were kept in the

spring for five years[8] (as well as the emergence records for ten years). Evidently, regardless of the covercrop, once the soil temperature at a 6-inch level reaches 52° F (on heavy loam soil) the emergence will begin. As nearly as we can discover, no eggs are laid on covercrop if suitable fruit buds are available. Often, especially in dry years, scanty, native covercrops obtain; and in orchards where water for fall irrigation is not available to start the covercrop, little benefit is derived. In El Dorado and Nevada counties, on the other hand, severe injury occurs in orchards having permanent covercrops. Early plowing of the covercrop (before full bloom) should be avoided in thrips-infested districts because it both hastens and concentrates the emergence, thereby accentuating bud injury. In general, therefore, covercropping has little effect on heavy infestations and cannot be considered as important in cultural control.

TABLE 3

REDUCTION OF PEAR-THRIPS POPULATION BY DRY PLOWING*

Treatment	Depth of operation, in inches	Date	Per cent reduction in emergence, as compared with unplowed soil
Sonoma County, 1932–33			
"Chiseled" two ways	18	Sept. 21, 1932	44.3
Plowed	10	Oct. 9, 1932	63.8
Plowed	10	Sept. 22, 1932	87.6
Disked	6	Oct. 17, 1932	71.8
Plowed	12	Sept. 19, 1932	81.9
Plowed	8–10	Sept. 11, 1932	63.9
Sonoma County, 1933–34			
Plowed	12	May 15, 1933	93.3
Cross-plowed	12	June 17, 1933	
Disked	6–8	June 10, 1933	4.3
Plowed	10	Oct. 9–10, 1933	89.9
Plowed	10	Oct. 8–10, 1933	74.6
Plowed	8–10	Nov. 16–20, 1933	30.4
Solano County, 1935–36			
Plowed	12	Oct. 9, 1935	231.6 increase

* Based on emergence-trap records.

Plowing to reduce infestations has been tried occasionally since 1908. As mentioned above, early spring plowing has no value. By the time the larvae have matured and are dropping to the ground, most of the orchards have been disked. The rough surface provides ready access to the depth of the plowing; and, as discussed under the section on habits of the larva, the cells are made in the plow sole or undisturbed soil at a depth of 6 to 12 inches. Harrowing or disking while the larvae are entering the soil kills many mechanically,

[8] These data are not cited in detail, since the conclusions do not justify the necessary space for graphs.

but is not practical because they mature and leave the trees throughout a period of 2 to 3 weeks. Also, as Moulton (1909) showed, disturbing the soil either at this time or in summer tends to drive the larvae deeper.

In early experiments in the Santa Clara Valley, Moulton (1909) and Foster and Jones (1911) employed a moldboard plow, turning the soil in October, November, and December to a depth of 9 inches. One plowing and cross-plowing in November reduced the emergence by an average of 70 per cent and 98

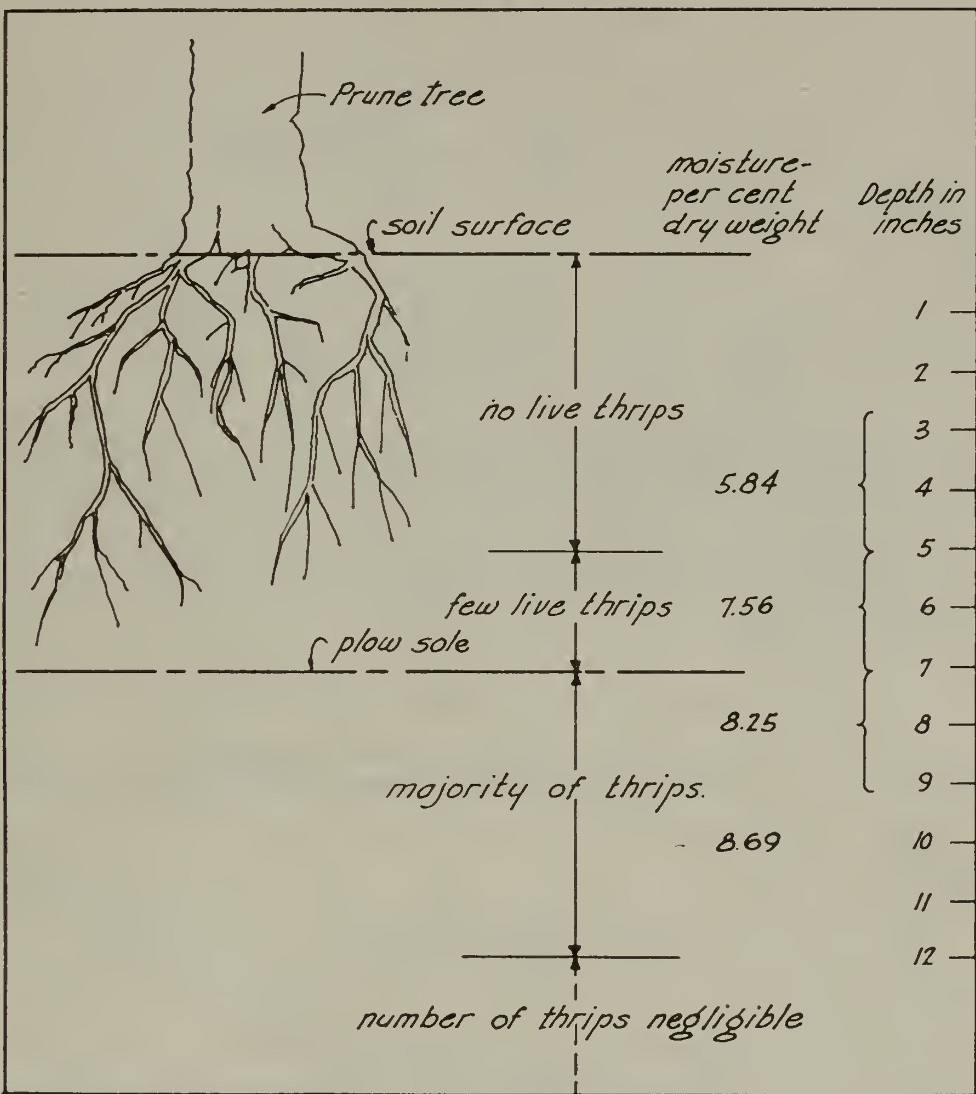

Fig. 24.—Vertical distribution of pear-thrips larvae in heavy clay loam of a nonirrigated prune orchard, and the soil moisture at corresponding levels. Practically no survival occurs at less than 8 per cent soil moisture (see fig. 25) or above the plow sole. In this schematic drawing, only the surface roots of the tree are indicated. (Suisun Valley, 1935.)

per cent respectively. As the plow sole has to be turned up, this control method is more effective in gravelly and sandy soils. Foster and Jones emphasized, however, that 60 to 80 per cent control was not sufficient to prevent bud injury the following spring in an epidemic. These experiments were based on the principle of mechanical injury, chiefly to the pupae; and plowing was delayed until fall rains began. In New York, Parrott (1912) considered fall plowing undesirable because of the danger of winter injury to the trees. In hilly areas, especially the California pear-growing districts, it is undesirable because of excessive erosion.

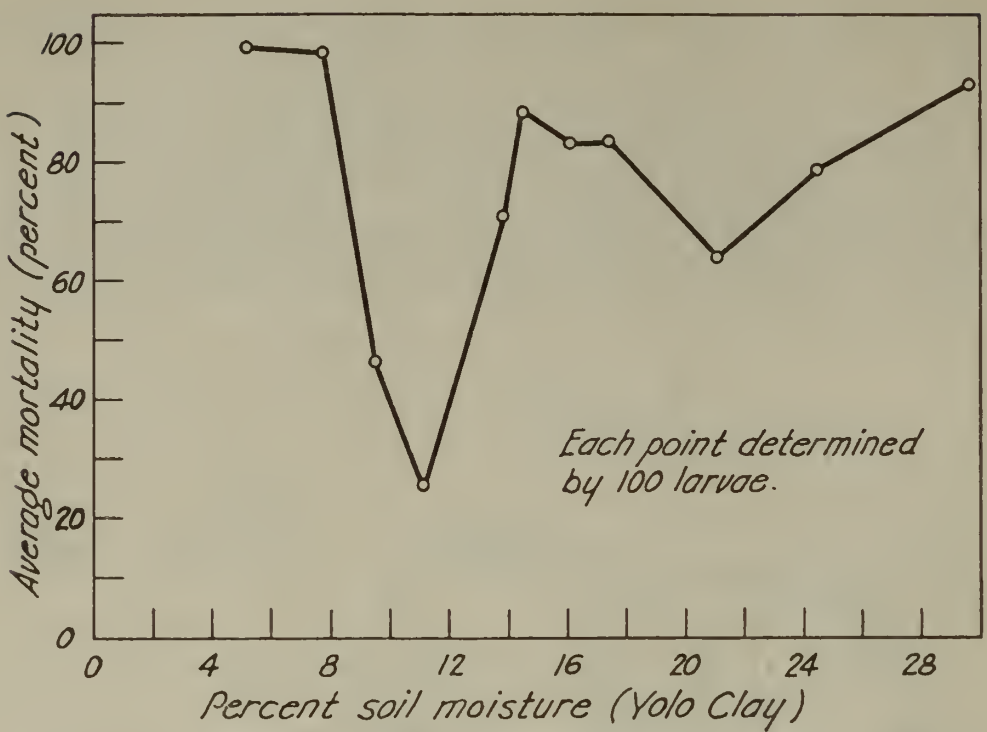

Fig. 25.—Mortality of pear-thrips larvae at 25° C. The optimum soil moisture for the larvae was determined by sealing them in jars of soil of a known moisture content. There were ten larvae per jar and ten jars of each per cent of soil moisture. Counts were made at 3-day intervals over a period of 24 days, and the results averaged. The time element, being of little importance in this experiment, has been disregarded.

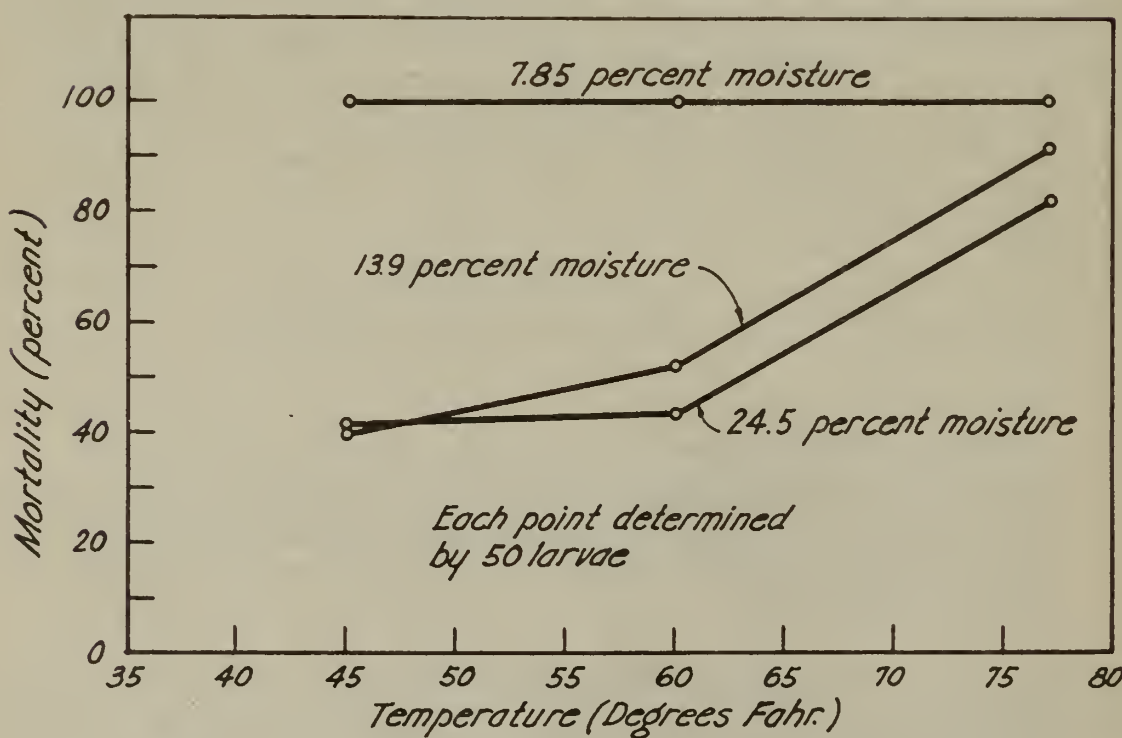

Fig. 26.—The marked effect of low soil moisture on the mortality of the thrips larva is illustrated in this experiment. In dry soil (Yolo clay) all the larvae died, irrespective of temperature; at normal summer soil moisture (13.9 per cent) and at field capacity (24.5 per cent) there was little difference in the mortality at a short exposure of 12 days. Temperatures above 60° F also increase the mortality, as is indicated.

During 1933 to 1937 a series of dry-fall-plowing experiments (table 3) were carried out in Solano and Sonoma counties, employing a slightly different principle. Since the larvae die readily if the soil moisture drops to or below about 9 per cent (figs. 24, 25; see also Bailey, 1934) the objective was to render the soil as dry and hot as possible. This operation could not be carried out until after harvest and depended on hot, dry weather for its success (figs. 26, 27, 28). It appeared also to have a place as a supplementary method of control for those who could not irrigate in the fall. The most effective tool was found to be a moldboard or single disk. Plowing one way, from the trees, and to a depth of about 12 inches, gave the best results.

Soil-temperature records were kept at a 6-inch depth in the plowed and unplowed areas. The difference in the daily means for the two areas in October and November was negligible, being 0 to 3 degrees Fahrenheit. The daily fluctuation in the unplowed soil was only 2 to 5 degrees, but was very marked, often as high as 20 degrees, in the plowed area. The maximum soil temperature during the October 1933 experiment was 75° F in the plowed and 67° in the unplowed area. In the 1935 plot the maximum temperature was 61° at 6 inches after plowing—too cool for the best results. This method in itself did not give a satisfactory reduction in the infestation the following spring. (See fig. 28 for the expected low mortality.) In addition, the disadvantages greatly limit its use. If early fall rains and cool weather occur, the clods do not dry out sufficiently; many of the disturbed larvae work down deeper and form a new cell (as in the 1935 plot in Solano County); the natural covercrop is disturbed; surface roots may be injured by the plow. All in all, this method of control, though effective in a dry season, has not been widely used.

Investigators have disagreed on the value of irrigation in the control of this insect. According to Moulton (1909), "Irrigating for thrips during any time of the year is entirely ineffectual." Foster and Jones (1911) obtained little or no control by this means. Essig (1920) reported, on the other hand: "Thorough irrigation by flooding has been practiced . . . and the results obtained have been excellent in practically all cases. . . . In some sections it is claimed that fall irrigation has not proved satisfactory, but in most cases this has probably been due to a lack of water to reach the young thrips before transformation to the adult stage has taken place." As the writer showed (1934), "whereas the larvae can withstand as much as 3 days' complete submergence in water, the pupae succumb within 20 hours when subjected to the same conditions." Spring irrigation directed against the larvae the last of April or the first of May, after they have left the trees and before they form cells, is moderately effective. Only in very dry years, however, would such an early-season irrigation be practical. After the larvae are well established in their earthen cells, summer and early fall irrigations have little effect. This fact is brought out by L. M. Smith (1933), who applied one, two, and three irrigations (6 acre-inches of water each time), the first on July 21, the second on August 28, and the third on September 29. In none of these plots was the emergence reduced the following spring.

Since the time of pupation in the fall varies, not only from season to season but in different parts of an orchard (depending on the amount of shade and soil moisture), fall irrigation is less effective than one might wish. Because of

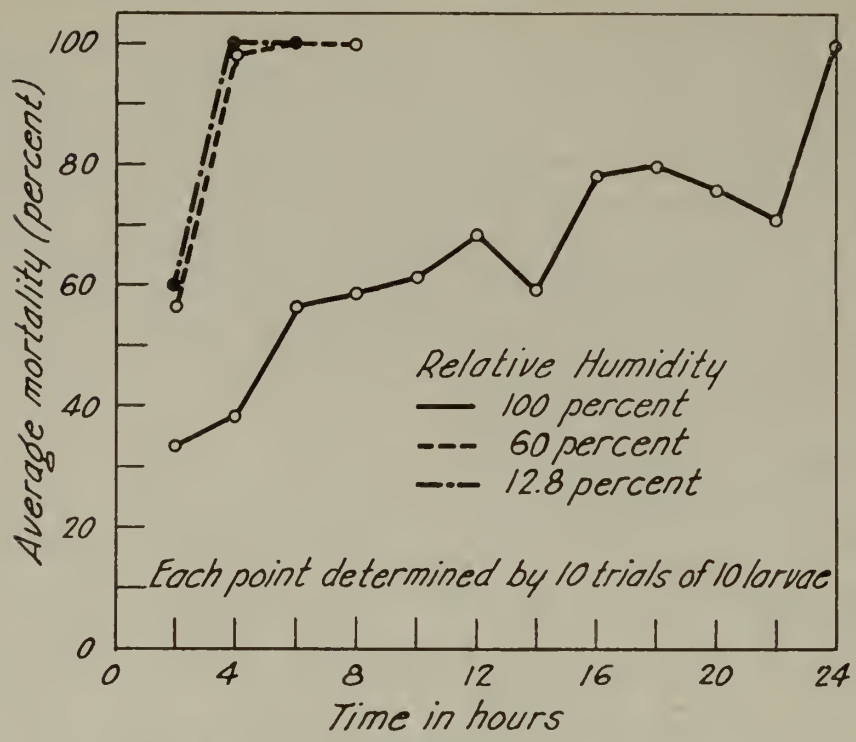

Fig. 27.—When removed from the soil and placed in glass containers in which the humidity was regulated by salt solutions, the larvae were killed very rapidly in an atmosphere of 60 per cent relative humidity or less.

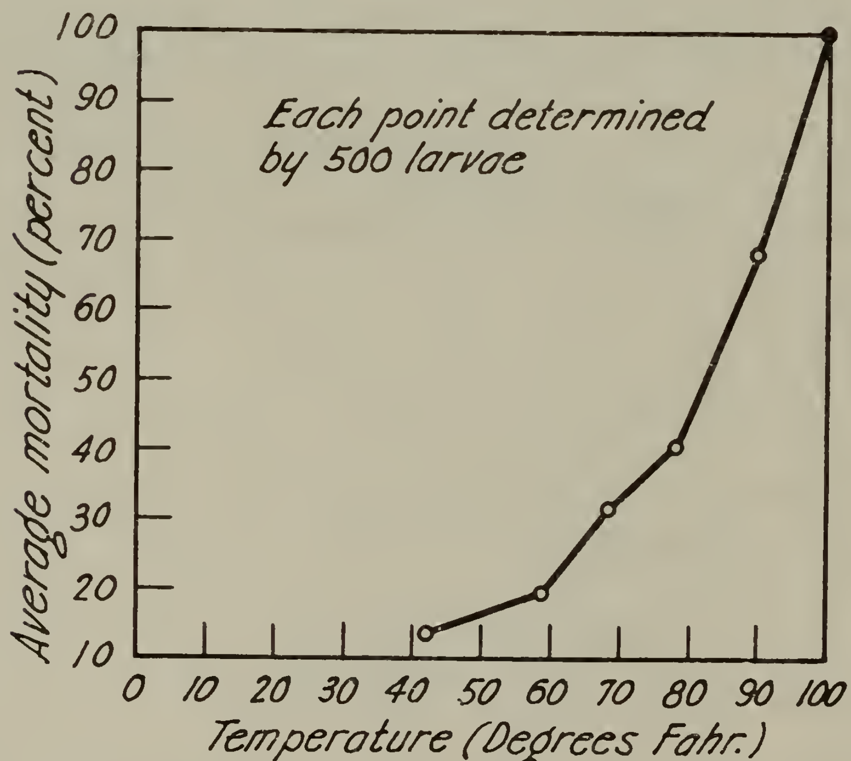

Fig. 28.—At an optimum soil moisture of 12.6 per cent, the mortality of the thrips larvae was in direct proportion to the increase in temperature. Counts were made at 3-day intervals over a period of 30 days. At temperatures below about 70° F, the time element is not important in the mortality rate.

this variability, no calendar date can be set for applying the water; and the most effective results can be obtained only by soil inspection for pupae. Irrigation should begin when the first pupae are found and may be continued about 2 weeks. The ditch method is not satisfactory; check or contour systems must be used, and 6 acre-inches or more of water applied. The longer a soil can be held at its field capacity, or nearly so, the greater the mortality resulting from this unfavorable condition. Results depend, in turn, upon the evaporating power of the air, the amount of soil moisture at irrigation time, the amount of water applied, and the type of soil itself.

In experiments reported in table 4, about 8 acre-inches of water was applied at each irrigation. The prune orchard was on heavy clay loam soil, and each plot of eight trees was replicated. Soil-moisture samples were taken each week (dry-weight basis) from October 16 to November 27, or until all pupae had transformed. Three cores at a depth of 6 to 12 inches were taken from each

TABLE 4

REDUCTION OF PEAR-THRIPS POPULATION BY FALL IRRIGATION, SOLANO COUNTY, 1935–36

Treatment	Date of plowing	Per cent reduction in emergence (spring, 1936), as compared with un-irrigated plots	Average soil moisture per cent, at 6–12 inches, sampled weekly, Oct. 16 to Nov. 27
Check (untreated)	....	....	12.02
Irrigated once (larval stage)	Oct. 17, 1935	88.3	19.05
Irrigated once (pupal stage)	Nov. 4, 1935	66.3	17.71
Irrigated twice (pupal stage)	Nov. 5–6, 1935	88.9	16.32

tree. Emergence traps were placed under each tree the following spring. The results bear out the laboratory findings that an increase in soil moisture above 15 per cent is detrimental (see figs. 25 and 29) to both the late larval stage and the pupae. The rain October 11–14 (about 2.2 inches) raised the moisture in the top 6 inches. Other irrigation experiments, in spring and fall, have given unsatisfactory results, chiefly because of variation in the soil types and in the infestation, which was manifested both by the water-holding capacity of the soil and by the extreme range in the number of adults caught in the traps.

Chemical Control.—Chemical control has included not only sprays and dusts, but fertilizers and soil fumigants. No results were obtained from early experiments with the materials available before 1910. Growers have applied sulfur and various fertilizers to the soil in an attempt to kill the emerging adults in spring, but with little success. The most recent work of this kind has been done by Breakey and his co-workers (1940), employing calcium cyanamid in prune orchards in Washington. The control averaged above 90 per cent with varying dosages of 100 to 300 pounds per acre. This material, applied in California on a small scale, gave no significant results. The most noticeable effect was the severe burning of the covercrop, which did not recover before the normal time of plowing.

Direct chemical control against the feeding stages on the trees has been prac-

ticed since about 1905. The earliest work, reported by Moulton (1905), included such spray materials as were available at the time—"soap washes and caustics, tobacco, sulphur, crude carbolic and creosote oils." The results were unsatisfactory. In later experiments, 1908 to 1910, the best control was obtained with a mixture of 2 to 3 per cent distillate oil emulsion and tobacco extract (diluted 1:50 to 1:2000, according to its strength). Three applications were advised: the first as soon as adults were found in the buds, the second 4 to 10 days later, and the third (for the larvae) after most of the petals had fallen. Whale-oil soap (2 to 5 pounds) was also commonly added to this spray. In severe infestations on pears, more than three applications were recommended. Maximum pressures used were about 180 to 200 pounds. Merrill

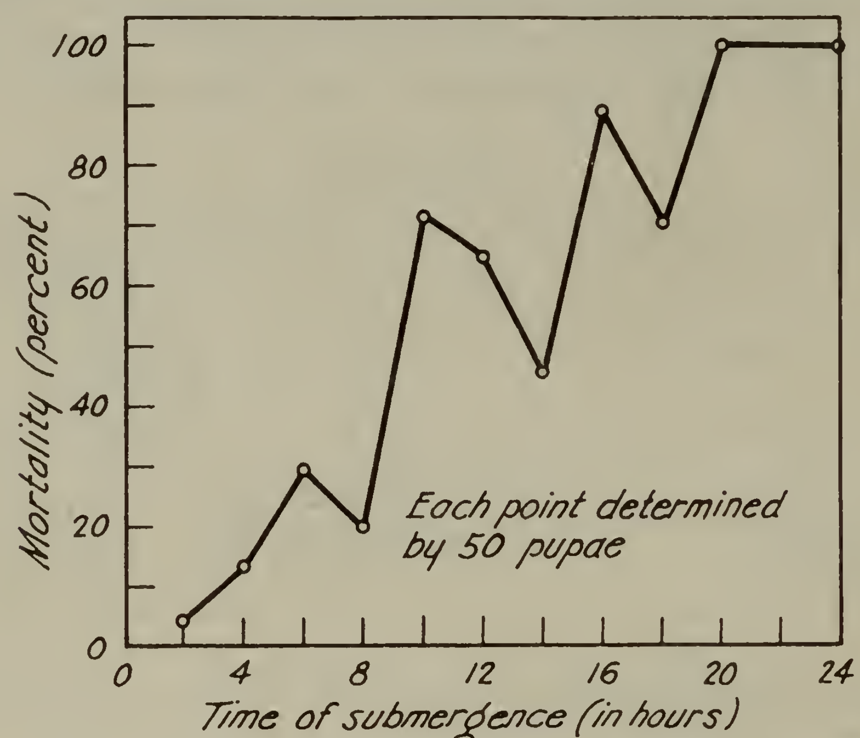

Fig. 29.—Pupae removed from the soil were taken to the laboratory and submerged in tap water at room temperature. Complete submergence (without air bubbles) for 20 to 24 hours was necessary to produce total mortality.

(1911–12) estimated the cost of one application per acre at $6.48; Foster and Jones (1911) at $9.59. Parrott (1912) in New York recommended 3 per cent kerosene emulsion with the nicotine. According to him, "two, or certainly not more than three, sprayings are required to afford efficient protection to the trees from the adult thrips." In addition, one or two applications were needed for the larvae.

Morris (1912) reported on the use of whitewash for controlling pear thrips. Eighty pounds of quicklime per 100 gallons of water was employed, and the opening buds were thoroughly coated. The adult thrips were thereby repelled or excluded from the pear buds. This experiment was conducted in 1910 and 1911. Heavy rains washed off an early application, making a second necessary in the 1911 season. Morris concluded: "We did not find it necessary to spray a second time for larvae, although in the first experiment enough larvae appeared to lead us to believe that in some cases a second spraying would be necessary with some good contact spray." This method was never widely used,

doubtless because of the large bulk of lime required, the necessary slaking procedure, and the readiness with which spring rains dissipated the protection.

In 1917, Cameron and his co-workers made cost studies on controlling this pest in British Columbia. According to Felt (1917), lime-sulfur was the most promising spray in New York.

A few years later, miscible oils became available; and these were used at from 2.5 to 5 per cent strength with nicotine sulfate. Some burning from this type of oil at the higher dosages was common. Also, the short spray gun began to replace the long rods; and higher pressures (300 pounds) were recommended (Phipps, 1921). Another development was the use of nicotine dusts. Essig wrote in 1920:

> Dusting for adult "black thrips" gave practically as good results as spraying. Dusting for "white thrips" was effective, killing all exposed insects, but was not quite so effective as a single spraying, owing to the greater penetrating power of oil sprays, but two dustings can be made at almost the same cost as one spraying, and if properly timed would give much better results than a single spraying.

Lovett (1921) gives further advice:

> The spray gun does not lend itself to successful thrips spraying. Use a rod fitted with an angle nozzle of the disc type. For the first application a disc with a fairly large aperture should be employed to afford a driving spray. Hold the nozzle close to the tree and drive the spray into the buds. For large trees the spray rig should be fitted with a tower to permit the spray to be applied from the proper angle.

Ten years later Wilcox (1931) also reported on this pest of prunes in Oregon. He recommended three sprays, as follows:

> First spray—when the winter buds are swelling, some showing green at tip. Second spray—when most of the winter buds are green at tip. Third spray—when most of the blossoms buds are white at the tip, pre-blossom spray. . . . The safest procedure would be to put on the first spray as soon as the thrips make their appearance. . . . If 100 or more thrips are present in 100 buds it would be advisable to put on at least one more spray. . . . If 200 or more thrips are present in 100 buds it would probably pay to put on all three sprays. . . . The outstanding material used in the three years [for which] we have positive results is dormant oil No. 5 (unsulfonated residue 65, viscosity 110°), 2 gallons, and nicotine sulfate 40%, 1 pint to 100 gallons of water.

Jones (1935, 1939) largely followed the same program.

Herbert (1927) reviewed the latest methods of application for controlling the pear thrips in the Santa Clara Valley.

From emergence records of 1932 in the Healdsburg district, L. M. Smith (1933) showed that even three to six applications of nicotine sprays and dusts (for both adults and larvae) failed to reduce the population appreciably the following year. The latest report on the necessity of control in England was given by Petherbridge and Thomas (1936, 1937), who used a derris-and-oil mixture with good success.

For nearly twenty-seven years, therefore, the best control was multiple nicotine applications. Such material was expensive and gave only moderately good results for the current season. In seasons of light infestation and heavy crops the injury was reduced to a minimum. The population in the orchards was not, however, reduced to the point where the control program could be relaxed the following year.

TABLE 5

PEAR-THRIPS-CONTROL EXPERIMENTS

Date treated	Crop	Formula of materials used*	Stage of thrips	Per cent control obtained, determined after the number of days given in parentheses†
		Nicotine compounds		
March 23, 1933	Prunes	Nicotine sulfate solution (40%), ¾ pt.; tank-mix dormant oil (100 vis., 60 U.R.‡), 1½ gal.; concentrated ammonia, ¾ pt.; casein spreader, ⅓ lb.......	Adult	27 (1)
March 26, 1934	Prunes	Nicotine sulfate solution (40%), 1 pt.; oil emulsion (80 vis., 60 U.R.), 1 gal......	Larva	86(1), 89(5)
March 30, 1934	Prunes	Nicotine sulfate solution (40%), 1 pt.; oil emulsion (80 vis., 60 U.R.), 1½ gal.	Larva	85(1)
April 1, 1936	Prunes	Nicotine powder (2.8% nicotine as alkaloid), 5 lbs.; oil emulsion (80 vis., 60 U.R.), ⅔ gal.........................	Larva	87(1), 55(5), 36(7)
April 1, 1936	Prunes	Nicotine sulfate solution (40%), ¾ pt.; oil emulsion (80 vis., 60 U.R.), ⅔ gal...	Larva	86(1), 63(5), 59(7)
April 18, 1938	Pears	Nicotine sulfate solution (40%), 1 pt.; lead arsenate, 4 lbs.; powdered spreader, ⅓ lb..........................	Larva	36(1), 40(3)
March 21, 1942	Pears	Fixed nicotine powder (4% nicotine as sulfate), 3 lbs.; nicotine sulfate solution (40%), ¼ pt.....................	Adult	21(2), 25(30)§
April 21, 1942	Pears	Fixed nicotine powder (14% nicotine as sulfate), 3 lbs........................	Larva	66(1), 91(3), 98(7)
		Thiocyanate		
March 26, 1934	Prunes	Organic thiocyanate (50%), 1 pt.; liquid spreader, 1 pt........................	Larva	64(1), 66(5)
April 21, 1942	Pears	Organic thiocyanate (50%), 1 pt.; oil emulsion (80 vis., 78 U.R.), 1 gal......	Larva	15(1), 12(3), 42(7)
		Pyrethrum compounds		
April 6, 1937	Prunes	Pyrethrum powder (1.5% pyrethrins), 20 lbs.; sulfur, 80 lbs.; applied as dust at 30 lbs. per acre.....................	Larva	43(2), 55(3)
April 9, 1937	Prunes	Pyrethrum extract (2.4% pyrethrins), 1 pt.; powdered spreader, ⅓ lb.; oil emulsion (60 vis., 92 U.R.), ⅓ gal.....	Larva	70(1), 78(2), 81(3)
April 14, 1937	Prunes	Invert emulsion of kerosene (1 gal. kerosene, 1 gal. water); pyrethrum powder (1.5% pyrethrins), ½ lb.; 14 gal. of mixture to the acre, applied with vapoduster..........................	Larva	45(1), 88(3), 1(9)
April 14, 1937	Pears	Pyrethrum powder (1.5% pyrethrins), 1½ lbs.; lead arsenate, 4 lbs.; wettable sulfur, 5 lbs..........................	Larva	90(2), 92(3)
April 14, 1937	Prunes	Pyrethrum powder (1.5% pyrethrins), 30 lbs.; sulfur, 70 lbs.; applied as dust 30 lbs. per acre........................	Larva	57(1), 64(3), 61(4), 76(5)
April 14, 1937	Prunes	Pyrethrum powder (2.4% pyrethrins), 10 lbs.; sulfur, 90 lbs.; applied as dust at 30 lbs. per acre.....................	Larva	68(1), 50(3), 33(4), 51(5)
April 18, 1938	Pears	Pyrethrum extract (2.4% pyrethrins), 1 pt.; lead arsenate, 4 lbs.; powdered spreader, ⅓ lb........................	Larva	53(1), 20(3)

* For footnotes, see end of table, p. 47.

TABLE 5 (*Continued*)

Date treated	Crop	Formula of materials used*	Stage of thrips	Per cent control obtained, determined after the number of days given in parentheses†
		Dinitro compounds (DNOCHP¶ and derivatives)		
April 20, 1938	Prunes	Sodium salt of DNOCHP (active ingredients, 40%), 0.8 lb.; wetting agent, 2½ oz.	Larva	0(1), 30(2), 586
April 12, 1938	Prunes	Sodium salt of DNOCHP (active ingredients, 40%), 0.2 lb.	Larva	19(1), 57(3), 26(4)
April 19, 1938	Prunes	DNOCHP dust (in walnut-shell flour), 1%; applied as dust at 35 lbs. per acre	Larva	80(1), 33(2), 24(4)
April 23, 1938	Prunes	DNOCHP dust (in walnut-shell flour), 1%; applied as dust at 35 lbs. per acre	Larva	9(1)‖, 34(2), 63(5)
April 9, 1939	Prunes	DNOCHP dust (in walnut-shell flour), 1%; applied as dust at 35 lbs. per acre	Larva	94(1), 91(2), 75(3), 86(4), 95(5)
April 7, 1939	Prunes	DNOCHP dust (in walnut-shell flour), 1%; applied as dust at 75 lbs. per acre	Larva	62(1), 28(3), 0(5)
April 4, 1939	Prunes	Triethanolamine salt of DNOCHP (active ingredients, 40%), 0.8 lb.; blood albumen, 2 oz.	Larva	65(1), 80(2), 70(3), 66(4), 77(5)
April 4, 1939	Prunes	Sodium salt of DNOCHP (active ingredients, 40%), 0.8 lb.; blood albumen, 1 oz.	Larva	55(1), 67(2), 66(3), 58(4), 62(5)
April 5, 1940	Prunes	DNOCHP** dust (0.9%) in frianite, applied as dust at 40 lbs. per acre	Larva	34(1), 60(2), 60(3), 66(4), 70(5)
April 5, 1940	Prunes	DNOCHP** dust (0.4%) in frianite, applied as dust at 40 lbs. per acre	Larva	13(1), 28(2), 0(3), 8(4), 12(5)
April 11, 1940	Prunes	DNOCHP** dust (0.9%) in frianite, applied as dust at 50 lbs. per acre	Larva	57(1), 92(2), 60(3), 80(4), 100(5)
April 11, 1940	Prunes	DNOCHP** dust (0.4%) in frianite, applied as dust at 75 lbs. per acre	Larva	87(1), 100(2), 100(3), 100(4), 100(5)
April 12, 1941	Pears	DNOCHP** powder (0.9%, with 1.8% petroleum oil, unclassified), 6 lbs.; acid arsenate of lead, 4 lbs.	Larva	70(3), 78(9)
April 12, 1941	Pears	DNOCHP** (as above), 3 lbs.; acid arsenate of lead, 4 lbs.	Larva	79(3), 71(9)
May 7, 1941	Pears	DNOCHP** (as above), 3 lbs.; acid arsenate of lead, 4 lbs.; powdered spreader, ⅓ lb.	Larva	47(3)
April 21, 1941	Pears	DNOCHP (20% dicyclohexylamine salt), 3 lbs.	Larva	45(1), 73(3), 90(7)
April 21, 1942	Pears	DNOCHP (as above), 1½ lbs.; acid lead arsenate, 3 lbs.; powdered spreader, ¼ lb.	Larva	48(1), 71(3), 96(7)
		Rotenone compounds		
April 6, 1937	Prunes	Rotenone dust (0.75%), 20 lbs.; sulfur, 80 lbs.; applied as dust at 30 lbs. per acre	Larva	41(2), 31(3)
April 6, 1937	Prunes	Cubé dust (0.75% rotenone), applied as dust at 17 lbs. per acre	Larva	17(1), 61(2)
April 12, 1937	Prunes	Cubé dust (0.75% rotenone), applied as dust at 35 lbs. per acre	Larva	73(2), 84(3), 74(5)
April 14, 1937	Prunes	Cubé dust (0.75% rotenone), applied as dust at 30 lbs. per acre	Larva	83(1), 75(4), 76(5)
April 14, 1937	Prunes	Cubé dust (0.75% rotenone); organic thiocyanate, 1%; applied as dust at 30 lbs. per acre	Larva	81(1), 91(4), 90(5)

TABLE 5 (*Continued*)

Date treated	Crop	Formula of materials used*	Stage of thrips	Per cent control obtained, determined after the number of days given in parentheses†
		Rotenone Compounds—(*Continued*)		
April 14, 1937	Prunes	Derris dust (0.75% rotenone), applied as dust at 40 lbs. per acre	Larva	86(4), 66(8)
April 28, 1938	Prunes	Cubé dust (0.75% rotenone), applied as dust at 35 lbs. per acre	Larva	62(1), 93(2), 96(5)
April 19, 1938	Prunes	Cubé dust (0.75% rotenone), applied as dust at 35 lbs. per acre	Larva	80(1), 60(2), 77(4)
April 8, 1939	Prunes	Derris dust (0.75% rotenone), applied as dust at 30 lbs. per acre	Larva	77(1), 60(2), 80(3), 85(5)
April 7, 1939	Prunes	Cubé dust (0.75% rotenone), applied as dust at 50 lbs. per acre	Larva	78(1), 60(2), 83(3), 93(5)
April 1, 1936	Prunes	Derris powder (about 0.7% rotenone), 5 lbs.; oil emulsion (80 vis., 60 U.R.), ⅔ gal.	Larva	80(1), 86(5), 66(7)
April 7, 1937	Prunes	Cubé powder (0.75% rotenone), 3 lbs.; liquid spreader, ½ pt.	Larva	60(1), 60(2), 71(3)
April 8, 1937	Plums	Derris powder (about 0.7% rotenone), 4 lbs.; blood albumen, 4 oz.; applied with vapoduster	Larva	49(2)
April 9, 1937	Prunes	Derris powder (about 0.7% rotenone), 4 lbs.; powdered spreader, 1 lb.	Larva	52(1), 65(2). 73(3), 84(5)
April 12, 1937	Prunes	Derris powder (about 0.7% rotenone), 6 lbs.	Larva	90(2), 94(3)
April 14, 1937	Pears	Derris powder (about 0.7% rotenone), 4 lbs.; lead arsenate, 4 lbs.; wettable sulfur, 5 lbs.	Larva	37(1), 52(2), 71(3), 28(4)
April 14, 1937	Pears	Derris powder (about 0.7% rotenone), 4 lbs.; lead arsenate, 4 lbs.; wettable sulfur, 5 lbs.	Larva	64(1), 48(2), 70(3), 59(4)
April 14, 1937	Prunes	Derris powder (about 0.7% rotenone), 4 lbs.; oil emulsion (60 vis., 92 U.R.), 1 gal.	Larva	71(1), 82(2), 82(3), 75(4), 71(5)
April 14, 1937	Prunes	Invert emulsion of kerosene without extra water; derris powder (about 0.7% rotenone), 1 lb.; 8 gal. per acre, applied with vapoduster	Larva	72(1), 0(9)
April 14, 1937	Pears	Derris powder (about 0.7% rotenone), 4 lbs.; lead arsenate, 4 lbs.; wettable sulfur, 5 lbs.	Larva	84(2), 86(3)
April 18, 1938	Pears	R-P powder,†† 5 lbs.; lead arsenate, 4 lbs.; wettable sulfur, 5 lbs.	Larva	70(1), 95(3)
April 20, 1938	Prunes	R-P powder, 6 lbs.	Larva	20(1), 73(2), 100(6)
April 20, 1938	Prunes	R-P powder, 5 lbs.	Larva	10(1), 50(2), 72(6)
April 4, 1939	Prunes	R-P powder, 5 lbs.	Larva	56(1), 87(2), 86(3), 87(4), 83(5)
April 4, 1939	Prunes	R-P powder, 5 lbs.; oil emulsion (60 vis., 90 U.R.), ½ gal.	Larva	75(1), 85(2), 87(3), 87(4), 80(5)
April 4, 1940	Prunes	Derris extract (2.5% rotenone), 1 qt.	Larva	83(1), 54(2), 86(3), 82(4), 85(5)
April 12, 1941	Pears	R-P powder, 5 lbs.; acid lead arsenate, 4 lbs.	Larva	88(3), 81(9)
May 7, 1941	Pears	R-P powder, 5 lbs.; acid lead arsenate, 4 lbs.; powdered spreader, ⅓ lb.	Larva	93(3)
March 21, 1942	Pears	R-P powder, 4 lbs.	Adult	14(2), 11(30)§

TABLE 5 (*Concluded*)

Date treated	Crop	Formula of materials used*	Stage of thrips	Per cent control obtained, determined after the number of days given in parentheses†
		Antimony compounds		
April 4, 1940	Prunes	Tartar emetic (potassium antimony tartrate), 4 lbs.; table sugar, 4 lbs.....	Larva	16(1), 45(2), 82(3), 84(4), 98(5), 95(6), 94(8), 100(10)
April 9, 1940	Prunes	Tartar emetic, 2 lbs.; table sugar, 2 lbs...	Larva	71(1), 90(2), 91(3), 95(4), 100(5)
April 12, 1941	Pears	Tartar emetic, 3 lbs.; table sugar, 3 lbs.; acid lead arsenate, 4 lbs...............	Larva	96(3), 98(9)
May 7, 1941	Pears	Antimony citrate, 3 lbs.; table sugar, 3 lbs.; acid lead arsenate, 4 lbs.; powdered spreader, ⅓ lb..................	Larva	89(3)
May 7, 1941	Pears	Tartar emetic, 1½ lbs.; table sugar, 1½ lbs.; acid lead arsenate, 4 lbs.; powdered spreader, ⅓ lb..................	Larva	90(3)
March 21, 1942	Pears	Tartar emetic, 2 lbs.; molasses, 1 qt.....	Adult	77(2), 81(30)§
April 29, 1942	Pears	Tartar emetic, 2 lbs., honey, 3 lbs.......	Larva	98(3), 95(7)

* All spray dilutions on basis of total volume of 100 gallons.
† Reduction in relation to infestation on unsprayed trees.
‡ Unsulfonated residue.
§ Based on larval count.
¶ Dinitro-ortho-cyclohexylphenol; hereafter referred to as DNOCHP.
‖ Reduced kill occurs during cool weather.
** These preparations are made up from material containing 1.5% dicyclohexylamine salt.
†† R-P ingredients: rotenone from cubé, 0.58%; other ether extractives from cubé, 1.16%; pyrethrins, 0.06%; petroleum oils (unclassified), 17.00%; petroleum sulfonates, 3.12%.

During the last serious epidemic, two factors focused attention on the inadequacy of such contact insecticides—namely, the increased loss despite the expensive control program; and the very low price of fruit. The demand was acute for a cheaper and more effective control to protect the fruit from scarring and reduce bud injury the following year. Preliminary results of experimental work were indicated by the writer (1938). At that time it was stated that of the newer materials, the rotenone-bearing dusts and sprays, which continued to kill the larvae up to 5 days after application, were the most satisfactory.

Over a period of six years many types of rotenone sprays and dusts have been tested, with the results shown in table 5. The strength of these prepared materials varied from 0.5 to 5 per cent rotenone; and liquid concentrates, as well as dusts and spray powder, were applied on pears and prunes for adults and larvae. In comparison with other products such as pyrethrum, nicotine, thiocyanates, and dinitro compounds, the rotenone-bearing products were outstanding. During the last three years, however, the experimental work has shown a poison-bait spray, tartar emetic and sugar, to be equal to rotenone—sometimes better. These two products are so much more effective than all others chiefly because the residue remains toxic to the newly emerging adults or newly hatching larvae for some time after application. One often hears that rotenone will kill thrips for 7 to 10 days after being applied. In our experience 5 days is the maximum period of practical effectiveness. If application is made near the time the adults have completed egg laying and are dying, or as the larvae are maturing and leaving the trees, the control appears better

than it actually is. The poison-bait spray, however, remains effective much longer than rotenone.

The writer has conducted many experimental plots and made thousands of field counts. Since a complete tabulation appears undesirable here, the methods will be briefly discussed, and some of the more pertinent experimental data will be presented.

Field counts of the thrips on the trees were based on the number of adults per bud or the number of larvae per fruit cluster. Bud counts necessitate picking the buds to pieces. Larval counts were obtained by tapping each cluster three times on a piece of black cardboard 6 × 4 inches. Though not all of the larvae were shaken out by this method, the data are comparable. All counts were made from the ground, because trial counts from a ladder at the different levels had been analyzed statistically and the greatest variation found in the treetops. Fifty clusters from each plot formed the basis for all counts.

Where feasible, spray plots were conducted in orchards from which trap records were available or for which the history of the previous infestation was known. Counts before spraying were made in all cases possible. Since the writer was dependent on the growers for the use of spraying and dusting equipment, the applications were not made at a standardized pressure or speed. Orchards or portions of orchards having the heaviest and most uniform infestations were selected for the test plots. Sometimes it was possible to obtain the emergence records the following year from treated plots; but these data do not reveal the actual control, since emergence from the check plots and local migration of the adults, especially in small plots, quickly cause reinfestation and mask the results.

The larger part of the chemical control plots were directed chiefly against the larval stage because the control thus obtained is more efficient than on the adult stage.

In the experiments with nicotine, satisfactory control was not secured with any compound or combination used, including nicotine sulfate with and without oil emulsions, as well as fixed nicotine compounds. Although fixed nicotine powder of 14 per cent strength gave a very satisfactory kill, its high cost will probably preclude its general use for thrips.

Thiocyanates were also unsatisfactory.

Pyrethrum compounds on the whole gave poor control. In only one test, when pyrethrum was combined with wettable sulfur and lead arsenate, was a practical reduction in the population obtained.

In the past five years various dinitro compounds were introduced as insecticides. Those that appeared promising for thrips control were tested. Although the dusts were effective, they caused burning of the leaves because the weather was unseasonably warm. Such dust (used at 50 to 75 pounds per acre) costs too much to be practical. In the 1942 spray plots DNOCHP (dicyclohexylamine salt, 20 per cent) used at less than 1½ pounds per 100 gallons of water, did not give adequate control; and at 1½ pounds or more, burning occurred.

The data selected for table 5 illustrate several points regarding the rotenone products tested. Effective control is not obtained with less than 30

pounds of dust per acre. The initial kill usually is not high (without pyrethrum), but continues up to 5 days, after which it falls off rapidly. Liquid rotenone extracts in general were inferior to spray powders. Results with the derris powder as used in 1937, at about 0.7 per cent strength, were compared with those of later tests in which pyrethrum was added; the kill is definitely improved when the two materials are used together. This material (called R–P powder commercially) has been employed in recent years by the growers in large quantities and very successfully combined with oil, wettable sulfur, or lead arsenate. At less than 4 pounds to 100 gallons of water, it does not

Fig. 30.—Left, thrips-injured pear buds from an unsprayed plot; right, a twig from an adjacent plot sprayed the previous year with tartar emetic and sugar.

give adequate control. Airplane applications observed have not proved effective. Invert emulsions or atomized concentrates have not been widely used, since in general they do not penetrate the fruit clusters.

The most recent newcomer in the field of thrips control has been tartar emetic. When used with sugar at not less than 2 pounds of each to 100 gallons of water, it has produced remarkable results (figs. 30 and 31; see table 5 for counts). When it was combined with acid or standard lead arsenate the burn was insignificant or nonexistent. Preliminary tests combining tartar emetic with bordeaux (5–5–50) gave no burn; with 2 per cent liquid lime-sulfur a peculiar brown residue was deposited, but no burn occurred; with 5 pounds of wettable sulfur the burning was severe. These sprays were applied to pears in the calyx stage. Honey and molasses as sugar substitutes

gave inferior control; both, but especially honey, dissolve so slowly in cold water that their use is not practical under normal spraying conditions. Apparently the deposit remains effective as long as thrips are on the trees; but heavy spring showers lessen its value. Considerable work is still needed on various dilutions, possible deposit builders, and methods of applying such poison-bait sprays for pear thrips on deciduous fruits. Conceivably this insect may yet develop a resistance to tartar emetic, as the citrus thrips appears to have done after only three years of treatment.

To summarize, the most effective materials tested to date are, first, tartar emetic and sugar, 2 to 4 pounds of each per 100 gallons; second, rotenone-

Fig. 31.—Left, pear twigs from trees sprayed with tartar emetic and sugar to control the larvae; right, twigs from adjacent unsprayed trees, illustrating curled leaves and lack of fruit.

pyrethrum spray powder, 4 to 6 pounds per 100 gallons (according to its strength). The latter product should be first dissolved in a little water to form a smooth paste before being added to the tank. Figure 32 shows the correct time to apply the spray for the adults in relation to the stage of bud development (should local conditions justify an adult spray). In the long run, however, the best control is obtained from thorough and consistent spraying of the larvae while the trees are in the "jacket" stage (see figs. 2, 3).

SUMMARY

The pear thrips, *Taeniothrips inconsequens* (Uzel), was introduced into California, probably from continental Europe, about 1900 or possibly earlier. During the past forty years it has reached its limit of spread in this state, but is extending its limited range in North America as well as in both hemispheres in deciduous-fruit-growing areas.

This thrips has been found on numerous native plants, but is most abundant and injurious on pear, prune, plum, and cherry.

Within its range in north-central California, the degree of injury fluctuates from district to district and from year to year. In epidemic years many orchards lose nearly the entire crop. Though the average yearly financial loss cannot be accurately estimated, the thrips is unquestionably important: in Sonoma, Napa, Solano, and Santa Clara counties especially, it is a major pest on pear and prune.

Fig. 32.—Proper stage of bud development in the pear (left), Imperial prune (center), and French prune (right) for applying spray for the adult thrips.

Bud injury by the adults directly reduces the crop; and the scarring of fruit by the larvae seriously lowers the quality.

The winged adult thrips is dark brown, slender, and about $\frac{1}{16}$ inch long. In California, females only have been found. The larva when fully grown is about the same size as the adult, but is yellowish white. The minute eggs are inserted into the surface of the stems, leaves, and fruit; and the delicate pupal stage is passed in the soil under the trees. There is only one generation a year; the adults, emerging as the buds swell, begin to feed and to lay their eggs. Normally the peak of the emergence comes about March 12. By petal fall the larvae are hatched. In about 2 weeks they drop, fully grown, to the ground, where they make a cell at a depth of 6 to 12 inches. Transformation to the adult stage occurs within the cell during October and November. In dry years the thrips population and the subsequent injury are much greater than in wet years. The date when the rainfall comes, rather than the annual total, is probably the most important factor in causing the number of thrips to fluctuate.

This pest has no important natural enemies.

The growing of heavy covercrops retards the spring emergence for only a few days and has little value in epidemic years. Fall plowing, with a single plow to a depth of 12 inches, one way, moderately reduces the population, but in dry years only. The practice has more disadvantages than advantages. Irrigation during the pupal period in October, using contours or basins and applying 6 or more acre-inches of water, gives a good kill.

Of all the proprietary spray materials tested over the years, rotenone and a poison-bait spray made up of tartar emetic and sugar have given outstanding results. Rotenone spray powders (especially those to which pryethrum has been added) should be used at the rate of 2 to 6 pounds per 100 gallons of water, according to the strength of the rotenone. Products containing less than about 0.75 per cent rotenone are not practical. The same is true of rotenone dusts, of which not less than 35 pounds should be applied per acre. A spray containing 2 to 4 pounds of tartar emetic and an equal amount of sugar in 100 gallons of water gives excellent control. In general, sprays are more effective than dusts. All sprays and dusts are much more effective in reducing fruit injury and subsequent bud injury if directed against larvae rather than adults.

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